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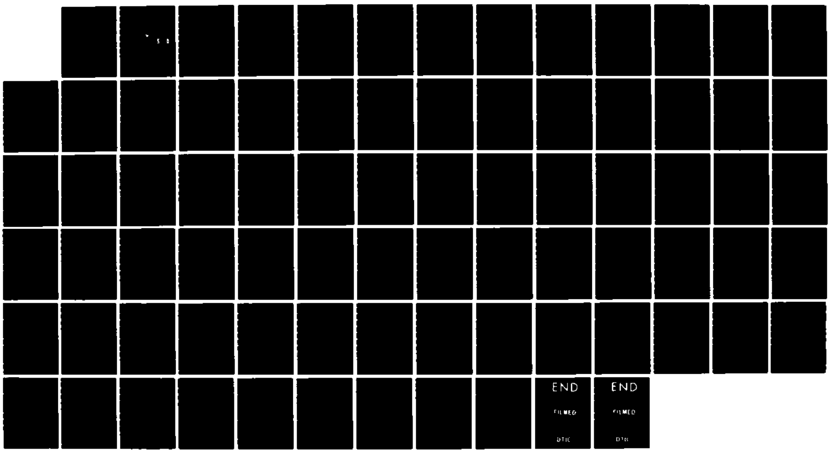

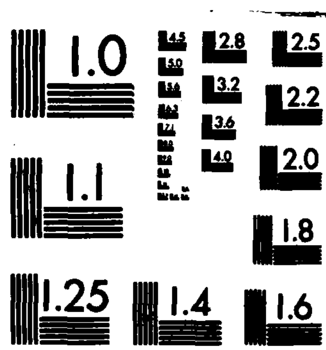

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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

AN ANALYSIS OF THE AMORE METHODOLOGY

by

Edward P. Negrelli

December 1984

Thesis Advisor: George Thomas

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The Analysis of Military Organizational Effectiveness (AMORE) methodology was developed in order to translate input degradation of military organizations into output capability as a function of time. Because this methodology requires an extensive amount of subjective, high resolution input by the user, there is a need to analyze the effects of input accuracy and of changes in the input information on the output generated

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An Analysis of the AMORE Methodology

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ABSTRACT

The Analysis of Military Organizational Effectiveness (AMORE) algorithm ~~methodology~~ was developed in order to translate input degradation of military organizations into output capability as a function of time. Because this methodology requires an extensive amount of subjective, high resolution input by the user, there is a need to analyze the effects of input accuracy and of changes in the input information on the output generated by the model. The purpose of this thesis ~~research effort~~ is to utilize sensitivity or parametric analysis to demonstrate the needed input accuracy, and to identify the effects of input changes on unit reconstitution capabilities. Through an analysis of the algorithms used in the AMORE simulation code, the assumptions and limitations inherent in the use of this methodology are identified, and recommendations concerning the applications of the methodology are provided. Recommendations for enhancements to the model are also presented.

Additional keywords: tables (data); Computerized Simulation; Monte Carlo method; charts.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

A. BACKGROUND

Traditionally, measures of unit effectiveness used in combat models have been based almost exclusively on attrition counts. These traditional models often use some explicit combat defeat criterion, such as thirty percent personnel incapacitation, to determine the viability of simulated combat units [Ref. 1]. In models such as these, the simulated unit reaching this criterion would be removed from further simulation, without regard to its reconstitution capabilities. One methodology which claims to offer an alternative to this traditional approach is called Analysis of Military Organizational Effectiveness, or AMORE.

The AMORE methodology was developed during the late 1970's by Science Applications Incorporated in order to translate input degradation of military organizations into output capability as a function of time. In contrast to other combat capability models, the AMORE approach treats time as a resource, and allows for the reconstitution and reorganization of military units after the onset of some initial degradation. This methodology was formally adopted by the U.S. Army in 1983 when the Commanding General of the U.S. Army Training and Doctrine Command (TRADOC) directed that all "future requirements for new organizational designs will be supported by AMORE" [Ref. 2]. The purpose of this directive was to insure that new Army organizations are structured to provide the personnel and equipment necessary for the successful accomplishment of the organization's mission.

The AMORE methodology requires an in-depth analysis of a unit's mission, posture, and organization in order to generate the input needed to drive a computer simulation of the degradation and reconstitution processes. The degradation process is simulated using a Monte Carlo technique with the input damage probabilities, while a transportation algorithm is used to simulate the reconstitution process. The output is expressed as a percentage of the unit's initial capability, computed at specified user defined time increments. The computer simulation introduces a stochastic element to the degradation and substitution processes, but the output is primarily derived deterministically from the extensive user defined input required by the methodology.

This required input must be developed through a detailed functional analysis of a unit's organization in terms of both ersonnel and equipment, and must provide the following information:

1. Initial strengths, in terms of personnel skill levels and equipment types;
2. Substitutability, between personnel skill levels and between equipment types, expressed in terms of the amount of time required to effect a substitution;
3. Increments of unit capability, called mission essential teams or METs, consisting of personnel and equipment contributing to mission accomplishment;
4. Probability of initial degradation, defined for each personnel skill level and each equipment type;
5. Utility options as desired by the user, such as number of desired iterations and times at which to calculate capability.

B. PURPOSE

The AMORE computer simulation requires a large volume of item-level and individual-level input information. Because this methodology requires an extensive amount of subjective, high resolution input by the user, there is a need to analyze the effects of input accuracy and of changes in the input information on the output generated by the model. The purpose of this research effort is to utilize sensitivity or parametric analysis to demonstrate the needed input accuracy, and to identify the effects of input changes on unit reconstitution capabilities. By identifying the assumptions inherent in the use of this methodology and by illustrating the effects of input changes, this investigation will provide guidance and recommendations concerning the applications and limitations of the AMORE approach. This investigation will also provide guidance and insight to users of the AMORE model in the formulation of the required input information for unit capability analysis.

C. METHOD OF ANALYSIS

In order to conduct this sensitivity analysis, it was first necessary to select a suitable AMORE analysis of an existing military organization to be used as a base case. (Details of the base case organization are provided in Chapter III). This base case serves as a surrogate organization for which the fundamental algorithms could be validated, the input parameters could be manipulated selectively, and the corresponding changes in output could be examined comparatively.

AMORE simulations will be run on the base case, after systematically varying each of the following selected input parameters, while holding all other input parameters constant:

1. Number of Iterations
2. Personnel Degradation Levels
3. Materiel Degradation Levels
4. Personnel Substitution Times
5. Materiel Substitution Times
6. Equipment Repair Times
7. Commander's Decision Times
8. Mission Essential Team Composition.

Through graphic representations of the output generated by these AMORE runs, demonstrations of the effects of changing each of the above parameters will be provided. An analysis of the algorithms used by the AMORE model will be conducted in order to examine the process by which the model transforms the input information into measurements of organizational capability. Based on the examination of these analytical and graphical results, the assumptions inherent in the use of the AMORE methodology will be identified, and recommendations regarding the formulation of AMORE input will be provided. Recommendations to correct any detected inconsistencies or errors in the AMORE program will also be provided.

II. ANALYSIS OF THE AMORE ALGORITHM

According to existing documentation, the AMORE methodology was specifically designed to provide the decision maker with an improved organizational capabilities model possessing the following features:

1. Provides for the assessment of the joint effect of personnel casualties and materiel damage upon the organization; and
2. Provides for the measurement of effectiveness as a function of time after the initial degradation [Ref. 4: p.1-2].

The AMORE model, not unlike other capabilities models, is an abstraction of the complex processes which determine the true capability of an organization. However, the definition of capability used by the AMORE approach and the simplifying assumptions used by this particular abstraction have not been stated explicitly in any of the existing documentation. In order to identify the assumptions inherent in the use of the AMORE methodology, an analysis of the algorithms used in the model must be conducted. This analysis examines the structures of the AMORE computer code in order to list the assumptions and to identify the limitations inherent in the use of these algorithms and structures.

A. THE AMORE MEASURE OF EFFECTIVENESS

The AMORE documentation states that "the best units are those which maximize capability for any given surviving resources" [Ref. 4: p.2-86]. Accordingly, the developers of the AMORE methodology have inferred a unit design goal based on a measure of effectiveness characterized by "maximum capability."

The quantification of capability for a military organization is subject to a wide range of interpretation. The AMORE methodology defines this capability in terms of the contribution of available assets toward mission accomplishment. Contribution, as interpreted by the developers of this methodology, can exist in two forms:

1. the availability of an asset to perform its designated mission essential function; and
2. the availability of an asset to perform a mission essential function other than its own (via substitution).

Based on this interpretation, the AMORE measure of effectiveness equates the determination of cabability to the quantification of these two forms of contribution. In order to accomplish this quantification, the AMORE approach requires the use of a computer simulation to accomplish two primary functions:

1. the transformation of user provided information into a set of assets available for contribution; and
2. the transformation of the available assets into a measure of capability.

In this way, the AMORE approach infers that capability is a function of availability. Instead of computing capability measurements directly, the AMORE methodology requires the user to specify levels of capability in increments called mission essential teams, and the computer simulation is used to map the availability of surviving assets onto this user defined structure. The AMORE simulation is designed to seek the maximum capability level, defined by the user, through the allocation of available assets. The parameters which determine both capability and availability are defined by the user provided input information. A detailed explanation of how this input information interfaces with the AMORE algorithms is presented in the following sections.

B. DETERMINATION OF SURVIVING ASSETS

Rather than require the user to specify a "typical" set of surviving assets, the AMORE model uses the following input information in order to determine one set of survivors:

1. initial strengths, defined for each personnel skill level and for each type of equipment; and
2. probabilities of degradation, defined for each personnel skill level and for each type of equipment.

Based on this information, a Monte Carlo technique is run for each person and for each item of equipment in order to determine the elements of the set of surviving assets.

This process occurs in a subroutine which is imbedded within an iteration loop. The purpose of the iteration loop is to generate output based on a sample consisting of numerous sets of surviving assets, as opposed to output based on an average set of survivors.

C. TRANSFORMATION OF ASSETS INTO CAPABILITY

The AMORE algorithm transforms each set of surviving assets into a measure of organizational capability. This transformation primarily involves a comparison between the current set of assets available and the set of assets required to achieve some predetermined level of capability.

Through the input of a mission essential team structure, the user has defined levels of capability based upon the assets required to fulfill each level. For example, in the base case organization, 8 mission essential teams (or levels of capability) were established as input. Based on this input, first level of capability requires that all the assets of the first team be fulfilled; the second level of capability requires that all the assets of the first two teams be fulfilled; ect. In this way, capability, defined

for the base case by 8 teams or increments, is specified in terms of 8 sets of required assets. The mission essential team information input by the user provides the structure against which the set of surviving assets can be compared.

In conducting this comparison, the AMORE model seeks the highest level of required assets that can be satisfied by the surviving assets. It accomplishes this by recognizing that some surviving assets may be substituted for others at a cost. The cost is expressed in terms of time, and this information is provided by the user in the following forms of input: substitution times, repair times, and decision times.

In order to find the highest level of capability that can be satisfied by a given set of surviving assets, the AMORE algorithm seeks a feasible solution to a linear program formulated as an assignment problem. This formulation is displayed in Figure 2.1.

The costs, C_{ij}, are defined by the transfer times provided by the user. The set of available assets, S_i, is defined by the set of survivors for the current iteration. The user provided mission essential team structure defines numerous sets of required assets, sets of D_j. One set of required assets, D_j, is defined for each level of capability specified by the MET structure.

The AMORE algorithm is structured to make successive calls to a subroutine which seeks a feasible solution to this assignment problem. Each call is made using a different set of D_j values until the highest level of D_j values for which an optimal feasible solution exists is identified. This set of values corresponds to a specific mission essential team number. This number is then expressed as a fraction of the total number of teams possible, as permitted by the input MET structure. This fraction of total capability is interpreted by the

$i = 1,2,\ldots,m$	Survivor type (assignee)
$j = 1,2,\ldots,n$	Requirement type (assignment)
S_i	Quantity of type i available
D_j	Quantity of type j required
X_{ij}	Number of assignments, i to j
C_{ij}	Cost of assignment, i to j (in time units)

Minimize $\sum_i \sum_j C_{ij} X_{ij}$

Subject to:

$$\sum_j X_{ij} \leq S_i \quad \text{for all } i$$

$$\sum_i X_{ij} \geq D_j \quad \text{for all } j$$

$$X_{ij} \geq 0$$

Figure 2.1 Assignment Problem Formulation.

developers of the AMORE methodology to represent a quantification of the organizational capability of the given set of surviving assets.

For each iteration, this entire procedure is repeated twice; once for personnel assets and once again for materiel assets. In this way, the AMORE model treats the contribution of personnel assets separately from and independently of the contribution of materiel assets. Two measures of capability, one for personnel and another for materiel, are computed for each iteration. The model then selects the minimum of these two capability values, and the minimum value selected is then recorded as the maximum capability

for the given organization for that iteration. This entire process is imbedded within an iteration loop, and upon completion of all iterations, an average capability value is computed.

D. RECOVERY RATE

After the AMORE model has determined the highest level of requirements (D_j values) which can be satisfied by available assets, it then determines the assignments to be made in order to achieve this level. In this way, the solution to the problem shown in Figure 2.1 (the X_{ij} values) specifies the assignments to be made. These assignments are made according to the times when the designated assets become available. Each asset becomes available upon expiration of its respective and applicable substitution, repair, and decision times. Thus, the AMORE algorithm maps the availability of assets into an array indexed by time increments. This mapping is then used to determine the highest level of capability that can be satisfied at any given time increment following the initial degradation. The user can specify up to thirty time increments, and the model will provide capability measurements at each of these increments. According to the AMORE User's Handbook, this procedure provides the user with an indication of organizational recovery rate.

It should be noted that the recovery rate reported by the AMORE model is not necessarily the maximum recovery rate possible. The user must be aware that the reported rate is based on a solution to the problem which maximizes capability, not recoverability. The reported rate is an indication of the availability of those assets which are required to achieve the highest possible level of capability. Recovey rates based on sub-optimal solutions to the assignment problem are not reported by the model.

E. COST OF ASSIGNMENTS

The AMORE methodology recognizes that surviving assets may be substituted to perform the mission essential functions associated with other assets. Substitutions are allowed at a cost, and this cost is expressed in units of time which are input by the user as transfer times. According to existing documentation, changing the transfer times will change the rate of recovery, but will not change the total capability recovered [Ref. 4: p.2-86]. However, it can be demonstrated that, by increasing selected transfer time values, higher levels of total capability can result. (See Chapter VI).

This suggests that, by increasing the costs, an optimal feasible solution can be found to satisfy a higher level of demands (a more restrictive set of D_j values). Examination of the objective function in Figure 2.1 reveals that this is not possible unless the increase in costs, C_{ij}, is accompanied by a change in the feasible region. The feasible region is defined by the constraint equations in Figure 2.1, which in turn are defined by the set of surviving assets and the set of required assets. The sets of required assets are established by the input MET structure and are not influenced by changes in input C_{ij} values. However, the sets of surviving assets are determined by a Monte Carlo process which draws upon a pseudo-random number stream generated in a subroutine of the AMORE program.

Examination of the sets of surviving assets generated by the base case AMORE run reveals that these sets are different from the sets generated by another AMORE run using the base case input data modified by increased transfer times. This gives an indication that changes in input transfer times can cause the model to draw random numbers from another section of the generated stream. This can

result in a different sample of sets of surviving assets for each complete AMORE run. Based on this observation, it is possible for the AMORE model to generate output which suggests that a higher level of capability may be achieved by increasing the transfer times. Because the structure of the AMORE algorithm allows this situation to exist, it is recommended that the user examine the confidence intervals which are provided as output for each of the capability values reported. When comparing the results of two or more complete runs, an examination of these confidence intervals will indicate if a significant difference exists between the maximum capabilities reported for each run. If a significant difference is found to exist, the user should increase the number of iterations and repeat the trials necessary for the comparison.

F. ASSUMPTIONS INHERENT IN THE MODEL

Based on an examination of the algorithms used in the AMORE program, the following assumptions inherent in the use of this model have been identified.

1. Capability can be quantified by measuring availability. The model assumes that each available asset will perform a mission essential function at an acceptable level of performance. Based on this assumption, the AMORE model measures exclusively the availability, not the performance, of each surviving asset.
2. Capability can be defined in discrete increments. The methodology requires that the user specify these increments as input to the model.
3. Increments of capability are additive. This assumption also suggests that the relationship between the number of increments and the levels (percentages) of

capability is linear. However, the relationship between the number of assets and the capability levels is not necessarily linear. The number of assets per increment (MET) is defined by the user, and the user is not restricted to assigning an equal number of assets to each increment. Therefore, even if the user defines the mission essential teams in a non-homogenous manner, the AMORE model will treat all mission essential teams as equally weighted increments of capability.

4. Maximum capability is determined independent of time. The model is structured to first conduct a feasibility check, which determines the maximum capability level that can be satisfied by the surviving assets, regardless of time. The algorithm then seeks to minimize time in the allocation of resources required to achieve this maximum level.
5. Personnel and materiel assets can be considered independently in the measurement of capability. The AMORE model is structured to consider personnel and materiel assets separately in determining capability levels. No synergistic effects between personnel and materiel assets are represented.
6. Surplus assets do not contribute to capability. The model is structured to allocate resources to discrete sets defined by user provided input. Surplus assets are considered by the model to contribute no additional value toward capability, unless the next entire increment is completed.

III. THE BASE CASE

A. SELECTION OF THE BASE CASE

An existing military organization was selected from a collection of completed AMORE analyses to provide the basis for parametrically analyzing the AMORE model. The input for this base case simulation could then be selectively changed to examine the effects on the output.

An appropriate base case organization would have to offer sufficient flexibility in terms of personnel skill levels, equipment types, and mission essential team composition, in order to make the desired changes to the input parameters. Several U.S. Army company-sized organizations were found to provide this flexibility. The organization selected for use as the base case is the Division-86 155mm Howitzer Battery, a Field Artillery unit consisting of 129 personnel and 76 major equipment items. This unit was selected because its wide range of personnel skill levels permits a flexible rearrangement of these personnel into several different mission essential team structures. A completed AMORE study, which compares the capabilities of alternative Division-86 155mm Howitzer Batteries, was published by Science Applications, Inc. (SAI) in July 1982 [Ref. 3]. This study served as a reference and source of information from which the input parameters used to run the base case simulation were developed.

B. COMPOSITION OF THE BASE CASE UNIT

The 129 personnel assigned to the Division-86 155mm Howitzer Battery are organized into sections as shown in Table I. This battery consists of eight howitzer sections

TABLE I

Personnel, Division-86 155mm Howitzer Battery

SECTION	SKILL	RANK/ GRADE	MOS	NO.
BTRY HQS	BTRY CDR	CPT	13E00	1
	FIRST SGT	E-8	13YM5	1
	FOOD SVC SGT	E-7	94B40	1
	SPLY SGT	E-6	76Y40	1
	NBC NCO	E-5	54E20	1
	FIRST COOK	E-5	94B20	1
	ARMORER	E-5	76Y20	1
	COOK	E-4	94B10	2
	COOK	E-3	94B10	1
	VEH DVR	E-3	13B10	1
COMMO SECT	TAC COM CH	E-6	31V30	1
	TAC WIRE OP CH	E-5	36K20	1
	TAC WIRE OP SPEC	E-4	36K10	1
	TAC WIRE OP SPEC	E-3	36K10	1
2 FIR PLT HQ	PLT LDR	LT	13E00	2
	PLT SGT	E-7	13B40	2
	VEH DVR	E-3	13B10	4
2 FDC	FIRE DIR OFF	LT	13E00	2
	CH FD CMPTR	E-6	13E30	2
	SR FD SPEC	E-5	13E20	2
	FD SPEC	E-4	13E10	2
	CP CARRIER DVR	E-4	13E10	2
	FD SPEC	E-3	13E10	4
8-HOW SECT	CH SECT	E-6	13B30	8
	GUNNER	E-5	13B20	8
	AMMO TM CH	E-5	13B20	8
	CANNONEER/ ASSEMBLER	E-4	13B10	8
	AMMO SPT VEH DVR	E-4	13B10	8
	SP HOW DVR	E-4	13B10	8
	CANNONEER	E-3	13B10	32
2 AMMO SECT	SECT CH	E-6	13B30	2
	AMMO SPEC	E-4	13B10	2
	AMMO HANDLER	E-3	13B10	2
	SR AMMO VEH OP	E-5	64C20	2
	AMMO VEH OP	E-4	64C10	4
				129

TABLE II

Equipment, Division-86 155mm Howitzer Battery

SECTION	EQUIPMENT	NO.
BTRY HQ	Radio Set AN/VRC 46.	2
	TRK, Utility, 1/4 ton, w/e.	2
	TKK, Cargo, 2 1/2 ton, 6x6.	2
	TRLR, Cargo 1/4 ton, 2 whl.	2
	TRLR, Cargo, 1 1/2 ton, 2 whl.	1
	TRLR, Tank, Water, 400 gal.	1
COMMO SETC	TRK, Cargo, 1/14 ton, 6x6.	1
	TRL, Cargo, 3/4 ton, 2 whl.	1
FIR PLT HQ	Aiming Circle.	6
	Radio Set AN/VRC-46.	2
	TRK, Utility, 1/4 ton, 4x4.	2
	TRK, Cargo, 1 1/4 ton, 6x6.	2
	TRK, Cargo, 2 1/2 ton, 6x6.	2
	TRL, Cargo, 1/4 ton.	2
	TRL, Cargo, 1 1/2 ton, 2 wh.	2
2 FDC	Carrier, CP, Lt. Trk.	2
	Computer, Gun Direction	2
	FD Set Artillery.	4
	Gen Set, Gas Eng.	4
	Radio Set, AN/VRC-46.	6
8 HOW SECT	Carrier, Cargo, Trkd, 6 ton.	8
	How, Med, SP, 155mm.	8
2 AMMO SECT	GOER, 8 ton.	6
	TRL, AMMO, 1 1/2 ton, 2 whl.	6

which are capable of operating in either a consolidated battery configuration or as separate four gun platoons, each with an associated platoon headquarters, fire direction center, and ammunition section. The Battery Headquarters section provides command and control, supply, food service, and NBC support, while communications support is provided by a separate Communications Section. The significant items of equipment for this battery, as specified by Table of Organization and Equipment (TOE) 6-367J, are presented in Table II.

C. INPUT TRANSFER MATRICES, PERSONNEL AND EQUIPMENT

The AMORE methodology requires as input an indication of which personnel skills can substitute for other skills. This required information is expressed in units of time, and it is input in the form of a personnel transfer matrix. The personnel transfer matrix for the base case organization is presented in Table III. The thirty-five skill levels present in the howitzer battery are arrayed in rows down the left side of the matrix and in columns across the top of the matrix. The entries in this matrix represent the amount of time, in minutes, required by the row skill level to substitute for the column skill level. Zeroes are entered along the main diagonal of this matrix, indicating that each individual can substitute for himself with zero time delay. The dashes in the matrix indicate that the personnel skill in that particular row cannot, or would not, substitute for the skill represented in that column (e.g., the cook in row 8 could not substitute for the battery commander in column 1 and the first sergeant in row 2 would not, although he could, substitute for the cannoneer in column 30).

An indication of equipment substitutability must also be input in the form of a transfer matrix. A substitutability mapping for the base case significant equipment items was developed, and is displayed in Table IV.

D. MISSION ESSENTIAL TEAMS (METS)

In order to compute unit reconstitution capability, the AMORE methodology also requires an indication of incremental unit capability, defined in terms of mission essential teams. Reconstitution capability is then determined by the number of teams which can be formed over time, after some initial degradation, by making permissible substitutions of personnel and equipment.

TABLE III

Personnel Transfer Matrix

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	Btry Cdr	0	-	-	-	-	-	-	-	-	-	-	-	-	-	0	-	-	60
2	1st Sgt	15	0	-	-	-	-	-	-	-	-	-	-	-	-	60	0	-	-
3	FdSvcSgt	-	60	0	30	-	0	-	0	0	-	-	-	-	-	-	-	-	-
4	SpplySgt	-	30	-	0	-	-	0	-	-	-	-	-	0	-	-	-	-	-
5	NBC Sgt	-	-	-	-	0	-	-	-	-	0	-	-	15	0	-	-	0	-
6	1st Cook	-	-	0	-	-	0	-	0	0	-	-	-	30	15	-	-	0	-
7	Armorer	-	-	-	30	-	-	0	-	-	0	-	-	15	0	-	-	0	-
8	Cook	-	-	30	-	-	0	-	0	0	-	-	-	60	30	-	-	30	-
9	Cook	-	-	-	-	-	30	-	0	0	60	-	-	120	60	-	-	60	-
10	Driver	-	-	-	-	-	-	-	-	-	0	-	-	120	60	-	-	0	-
11	CommoCh	-	60	-	-	-	-	-	-	-	-	0	0	0	-	-	-	-	-
12	Wire Ch	-	-	-	-	-	-	-	-	-	-	0	0	0	0	-	-	-	-
13	Wire Sp	-	-	-	-	-	-	-	-	-	0	30	0	0	0	-	-	0	-
14	Wire Sp	-	-	-	-	-	-	-	-	-	0	-	30	0	0	-	-	0	-
15	Plt Ldr	0	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	-	0
16	Plt Sgt	-	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
17	Driver	-	-	-	-	-	-	-	-	-	0	-	-	120	60	-	-	0	-
18	FD Off	60	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	-	0
19	FD Ch	-	60	-	-	-	-	-	-	-	-	30	-	0	-	-	60	-	30
20	SrFD Sp	-	-	-	-	-	-	-	-	-	0	-	-	15	0	-	-	0	60
21	FD Sp	-	-	-	-	-	-	-	-	-	0	-	-	30	15	-	-	0	-
22	CP Dvr	-	-	-	-	-	-	-	-	-	0	-	-	30	15	-	-	0	-
23	FD Sp	-	-	-	-	-	-	-	-	-	0	-	-	60	30	-	-	0	-
24	Ch Sec	-	60	-	-	-	-	-	-	-	-	-	-	-	-	60	0	-	-
25	Gunner	-	-	-	-	-	-	-	-	-	0	-	-	30	15	-	30	0	-
26	AmmoHdl	-	-	-	-	-	-	-	-	-	0	-	-	30	15	-	30	0	-
27	C/Assy	-	-	-	-	-	-	-	-	-	0	-	-	60	30	-	-	0	-
28	SV Dvr	-	-	-	-	-	-	-	-	-	0	-	-	60	30	-	-	0	-
29	SP Dvr	-	-	-	-	-	-	-	-	-	0	-	-	60	30	-	-	0	-
30	Cannonr	-	-	-	-	-	-	-	-	-	0	-	-	120	60	-	-	0	-
31	Ammo Ch	-	60	-	-	-	-	-	-	-	-	-	-	-	-	-	30	-	-
32	Ammo Sp	-	-	-	-	-	-	-	-	-	0	-	-	60	30	-	-	0	-
33	AmmoHdl	-	-	-	-	-	-	-	-	-	0	-	-	120	60	-	-	0	-
34	Veh Op	-	-	-	-	-	-	-	-	-	0	-	-	30	15	-	-	0	-
35	Veh Op	-	-	-	-	-	-	-	-	-	0	-	-	60	30	-	-	0	-

Table III

Personnel Transfer Matrix (cont'd)

	19	20	21	22	23	24	25	26	27	28	28	30	31	32	33	34	35
1 Btry Cdr	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2 1st Sgt	-	-	-	-	-	0	-	-	-	-	-	-	0	-	-	-	-
3 FdSvcSgt	-	-	-	-	-	-	-	15	-	-	-	-	60	-	-	15	-
4 SpplySgt	-	-	-	-	-	-	-	30	0	0	0	-	30	0	-	15	0
5 NBC Sgt	-	-	-	-	-	-	-	30	15	15	15	0	-	15	0	30	15
6 1st Cook	-	-	-	-	-	-	-	60	30	30	30	15	-	30	15	60	30
7 Armorer	-	-	-	-	-	-	-	30	15	15	15	0	-	15	0	30	15
8 Cook	-	-	-	-	-	-	-	120	60	60	60	30	-	60	30	120	60
9 Cook	-	-	-	-	-	-	-	-	120	120	120	60	-	120	60	-	120
10 Driver	-	-	-	-	-	-	60	30	0	0	0	0	-	0	0	30	0
11 CommoCh	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
12 Wire Ch	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
13 Wire Sp	-	-	-	-	-	-	-	120	60	60	60	30	-	60	30	120	60
14 Wire Sp	-	-	-	-	-	-	-	-	120	120	120	60	-	120	60	-	120
15 Plt Ldr	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
16 Plt Sgt	-	-	-	-	-	0	-	-	-	-	-	-	0	-	-	-	-
17 Driver	-	-	-	-	-	-	60	30	0	0	0	0	-	0	0	30	0
18 FD Off	0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
19 FD Ch	0	0	0	0	-	-	-	15	0	0	0	-	-	0	-	15	0
20 SrFD Sp	30	0	0	0	0	-	-	30	15	15	15	0	-	15	0	30	15
21 FD Sp	60	30	0	0	0	-	-	60	30	30	30	15	-	30	15	60	30
22 CP Dvr	60	30	0	0	0	-	-	60	30	30	30	15	-	30	15	60	30
23 FD Sp	-	60	30	0	0	-	-	-	60	60	60	30	-	60	30	-	60
24 Ch Sec	-	-	-	-	-	0	0	0	0	0	0	-	0	0	-	0	0
25 Gunner	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0
26 AmmoHdl	-	-	-	-	-	0	0	0	0	0	0	0	0	0	0	0	0
27 C/Assy	-	-	-	-	-	30	15	0	0	0	0	0	30	0	0	0	0
28 SV Dvr	-	-	-	-	-	30	15	0	0	0	0	0	30	0	0	0	0
29 SP Dvr	-	-	-	-	-	30	15	0	0	0	0	0	30	0	0	0	0
30 Cannonr	-	-	-	-	-	-	60	30	0	0	0	0	-	0	0	30	0
31 Ammo Ch	-	-	-	-	-	0	0	0	0	0	0	-	0	0	-	0	0
32 Ammo Sp	-	-	-	-	-	30	15	0	0	0	0	0	30	0	0	0	0
33 AmmoHdl	-	-	-	-	-	-	60	30	0	0	0	0	-	0	0	30	0
34 Veh Op	-	-	-	-	-	-	-	60	30	30	30	15	30	0	0	0	0
35 Veh Op	-	-	-	-	-	-	-	120	60	60	60	60	60	0	0	0	0

TABLE IV

Equipment Transfer Matrix

			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	AN/VRC-46	2	0	.	.	.	.	.	.	.	.	0	.	.	.	.	.	.	.	.	.	0	.	.	.	.
2	1/4T TRK	2	.	0	.	.	.	.	0	.	.	.	0	0	.	.	.	.	.	.	.	.	.	.	.	.
3	2 1/2T TRK	2	.	0	0	.	.	.	0	.	.	.	0	0	0	.	.	.	.	.	.	.	0	.	0	.
4	1/4T TRLR	2	.	.	.	0	.	.	.	0	.	.	.	.	.	0	.	.	.	.	.	.	.	.	.	.
5	1 1/2T TRL	1	.	.	0	.	0	.	.	0	.	.	.	.	.	0	0	.	.	.	.	.	.	.	.	0
6	WATER TRLR	1	.	.	.	.	.	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
7	1 1/4T TRK	1	.	0	0	.	.	.	0	.	.	.	0	0	0	.	.	.	.	.	.	.	.	.	.	.
8	3/4T TRLR	1	.	.	.	0	0	.	.	0	.	.	.	.	.	0	0	.	.	.	.	.	.	.	.	0
9	AIMINGCIR	6	.	.	.	.	.	.	.	.	0	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
10	AN/VRC-46	2	0	.	.	.	.	.	.	.	.	0	.	.	.	.	.	.	.	.	.	0	.	.	.	.
11	1/4T TRK	2	.	0	.	.	.	.	0	.	.	.	0	0	.	.	.	.	.	.	.	.	.	.	.	.
12	1 1/4T TRK	2	.	0	0	.	.	.	0	.	.	.	0	0	0	.	.	0	.	.	.	.	.	.	.	.
13	2 1/2T TRK	2	.	0	0	.	.	.	0	.	.	.	0	0	0	.	.	.	.	.	.	.	0	.	.	.
14	1/4T TRLR	2	.	.	.	0	0	.	.	0	.	.	.	.	.	0	0	.	.	.	.	.	.	.	.	.
15	1 1/2T TRL	2	.	.	.	.	0	.	.	0	.	.	.	.	.	0	0	.	.	.	.	.	.	.	.	0
16	CP CARRIER	2	.	0	.	.	.	.	0	.	.	.	0	0	.	.	.	0	.	.	.	.	.	.	.	.
17	GUNDIRCPTR	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	0	.	.	.	.	.	.
18	FDSETARTY	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	0	.	.	.	.	.	.
19	GEN SET	4	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.	.	.	.	.
20	AN/VRC-46	6	0	.	.	.	.	.	.	.	.	0	.	.	.	.	.	.	.	.	.	0	.	.	.	.
21	SPTVEHTRKD	8	.	.	0	.	.	.	.	.	.	.	.	.	0	.	.	.	.	.	.	.	0	.	0	.
22	SP HOW	8	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	0	.	.
23	GOER8T	6	.	.	0	.	.	.	.	.	.	.	.	.	0	.	.	.	.	.	.	.	.	.	0	.
24	TRLAMMO	6	.	.	.	0	0	.	.	0	.	.	.	.	.	0	0	.	.	.	.	.	.	.	.	0

TABLE V

Mission Essential Teams, Personnel

	MET 1	MET 2	MET 3	MET 4	MET 5	MET 6	MET 7	MET 8
Btry Cdr	0	0	0	0	1	0	0	0
First Sgt	0	0	0	0	1	0	0	0
Food Svc Sgt	0	0	0	0	0	0	0	0
Supply Sgt	0	0	0	0	0	0	0	0
NBC NCO	0	0	0	0	0	0	0	0
First Cook	0	0	0	0	0	0	0	0
Armorer	0	0	0	0	0	0	0	0
Cook	0	0	0	0	0	0	0	0
Cook	0	0	0	0	0	0	0	0
Veh Dvr	0	0	0	0	1	0	0	0
Tac Comm Ch	1	0	0	0	0	0	0	0
Tac Wire Ch	0	0	0	0	0	1	0	0
Tac Wire Sp	1	0	0	0	0	0	0	0
Tac Wire Sp	1	0	0	0	0	0	0	0
Plt Ldr	0	1	0	0	0	1	0	0
Plt Sgt	0	1	0	0	0	1	0	0
Veh Dvr	2	1	0	0	0	1	0	0
Fire Dir Off	1	0	0	0	0	0	0	0
Ch FD Cmptr	1	0	0	0	0	0	0	0
Sr FD Spec	1	0	0	0	0	0	0	0
FD Spec	1	0	0	0	0	0	0	0
CP Dvr	1	0	0	0	0	0	0	0
FD Spec	2	0	0	0	0	0	0	0
Ch Sect	1	1	1	1	1	1	1	1
Gunner	1	1	1	1	1	1	1	1
Ammo Tm Ch	1	1	1	1	1	1	1	1
Cannoneer	1	1	1	1	1	1	1	1
Ammo Veh Dvr	1	1	1	1	1	1	1	1
SP How Dvr	1	1	1	1	1	1	1	1
Cannoneer	4	4	4	4	4	4	4	4
Ammo Sect Ch	1	0	0	0	1	0	0	0
Ammo Spec	0	0	1	0	0	0	1	0
Ammo Hdlr	0	1	0	0	0	1	0	0
Sr Ammo Dvr	0	1	0	0	0	1	0	0
Ammo Dvr	1	0	1	0	1	0	1	0

For the base case organization, the mission essential teams are defined in terms of howitzer sections. The base case mission essential teams, defined for personnel, are displayed in Table V. The base case mission essential teams, defined for equipment, are presented in Table VI.

TABLE VI

Mission Essential Teams, Equipment

	MET 1	MET 2	MET 3	MET 4	MET 5	MET 6	MET 7	MET 8
Radio AN/VRC	0	0	0	0	1	0	0	0
Trk Ut 1/4T	0	0	0	0	1	0	0	0
Trk Cgo 2.5T	0	0	0	0	0	0	0	0
Trl Cgo 1/4T	0	0	0	0	1	0	0	0
Trl Cgo 1.5T	0	0	0	0	0	0	0	0
Trl Tank Wtr	0	0	0	0	0	0	0	0
Trk Cgo 5/4T	1	0	0	0	0	0	0	0
Trl Cgo 1/4T	1	0	0	0	0	0	0	0
Aiming Circl	1	1	0	0	1	1	0	0
Radio AN/VRC	0	1	0	0	0	1	0	0
Trk Ut 1/4T	0	1	0	0	0	1	0	0
Trk Cgo 5/4T	0	0	0	0	0	0	0	0
Trk Cgo 2.5T	0	0	0	0	0	0	0	0
Trl Cgo 1/4T	0	1	0	0	0	1	0	0
Trl Cgo 1.5T	1	0	0	0	1	0	0	0
Carrier CP	1	0	0	0	0	0	0	0
Computer, FD	1	0	0	0	0	0	0	0
FD Set, Arty	0	0	0	0	0	0	0	0
Gen Set, Gas	1	0	0	0	0	0	0	0
Radio AN/VRC	3	0	0	0	0	0	0	0
Trk Cgo 6T	1	1	1	1	1	1	1	1
How, 155SP	1	1	1	1	1	1	1	1
Trk Cgo 5T	1	1	1	0	1	1	1	0
Trl Ammo	1	1	1	0	1	1	1	0

This mission essential team structure is based on the 1982 SAI Report [Ref. 3: p.2-18] which presents the following considerations in forming the METs:

1. To form the first MET, there is need for a howitzer section, a minimal communications section, a fire direction center, and one element of an ammunition section. With only a single howitzer section, there is no need for either a platoon leader or a battery commander. Two drivers are included in the platoon headquarters, however, to drive the battery nuclear load vehicles.
2. With the addition of the second howitzer section, it is necessary to add the platoon leader, platoon sergeant, and driver. A second element of the ammunition section is also needed.
3. The addition of the third howitzer section requires only the addition of the remaining element of the first ammunition section while the addition of the fourth howitzer section requires no additions from the remainder of the battery.
4. The battery commander, first sergeant, and driver are added with the addition of the fifth howitzer section when the span of control capability of the first platoon leader begins to be exceeded.
5. The second platoon leader, platoon sergeant, driver and a wireman are added with the sixth howitzer section when splitting the battery into two 3-gun platoons becomes a possibility.
6. The addition of the three elements of the second ammunition section occurs with howitzer sections five, six and seven respectively.
7. No food service, supply, or NBC personnel are considered essential at any team level.

E. ADDITIONAL SIGNIFICANT INPUT DATA

1. Degradation Probabilities

In order to simulate an initial degradation of the unit under study, the AMORE methodology requires as input probabilities of degradation. Different probabilities can be entered for each personnel skill level and equipment type. For materiel, AMORE requires that degradation probabilities be defined for light, moderate and heavy damage.

For the base case, an input degradation probability of 20% was used for all personnel skill levels. The materiel damage probabilities used were based on the number of rounds of enemy artillery required to inflict the designated level of personnel damage. These materiel degradation probabilities are: for light damage, 31%; for moderate damage, 16%; and for heavy damage, 14%.

2. Repair and Decision Times

The AMORE methodology requires that the repair times for lightly and moderately damaged equipment be provided for each equipment type. The methodology does not permit repairs on materiel receiving heavy damage. For the base case, repair times were set at zero minutes for lightly damaged equipment, and at one minute for all moderately damaged equipment.

The AMORE methodology also provides for the simulation of delays in equipment substitutions, due to the additional time required by the unit commander to decide on the substitutions to be made. For the base case, all decision times were set at zero minutes.

It may seem apparent that the repair times and the decision times used as input for the base case do not provide realistic estimates of these events. However, these times were selected to facilitate the analysis of the base

case output, and to establish some base-line values upon which a sensitivity analysis could be conducted.

F. BASE CASE OUTPUT

The transfer times for materiel and personnel and the repair times for materiel are treated as means of exponentially distributed random variables, according to the AMORE User's Handbook [Ref. 4: p.2-7]. The times used during the simulation are sampled from the distributions described by the mean times. However, if the user desires to supress this sampling, a "mean time only" option may be selected. The user also has the ability to select the number of iterations to be run, and the AMORE output is based on the average of all iterations.

A 50-iteration run of the base case was conducted using the input described in the preceding paragraphs and using the mean time only option. Output from this run, shown in Table VII, reveals the mean fraction of capability for personnel and materiel evaluated at each of the user specified time slices. The column labelled "Minimum" contains the average values, for all iterations, of the minimum of the personnel and materiel capabilities. To illustrate how to read the output, note that after 0.75 hours, personnel regained a mean capability of 77.0 percent, while materiel reached a mean capability of 86.2 percent with a minimum or unit mean capability being 74.7 percent at that time. A 90 percent confidence limit, shown to the right of each of the mean capabilities, is also provided.

The unit capability values found in the Minimum Column of Table VII were plotted against the designated time values, and the resulting graph is displayed in Figure 3.1. This graphical representation can be used to provide a visual comparison between different AMORE runs. For

TABLE VII

TIME (HOURS)	PERSONNEL		MATERIEL		MINIMUM	
0.000	0.127	0.049	0.060	0.037	0.017	0.018
MINIMUM	0.000	0.000	0.000	0.000	0.000	0.000
0.062	0.497	0.084	0.862	0.029	0.482	0.082
0.125	0.497	0.084	0.862	0.029	0.482	0.082
0.187	0.497	0.084	0.862	0.029	0.482	0.082
0.250	0.515	0.084	0.862	0.029	0.497	0.081
0.312	0.515	0.084	0.862	0.029	0.497	0.081
0.375	0.515	0.084	0.862	0.029	0.497	0.081
0.437	0.515	0.084	0.862	0.029	0.497	0.081
0.500	0.770	0.034	0.862	0.029	0.747	0.034
0.562	0.770	0.034	0.862	0.029	0.747	0.034
0.625	0.770	0.034	0.862	0.029	0.747	0.034
0.687	0.770	0.034	0.862	0.029	0.747	0.034
0.750	0.770	0.034	0.862	0.029	0.747	0.034
0.812	0.770	0.034	0.862	0.029	0.747	0.034
0.875	0.770	0.034	0.862	0.029	0.747	0.034
0.937	0.770	0.034	0.862	0.029	0.747	0.034
1.000	0.802	0.016	0.862	0.029	0.775	0.019
1.062	0.802	0.016	0.862	0.029	0.775	0.019
1.125	0.802	0.016	0.862	0.029	0.775	0.019
1.187	0.802	0.016	0.862	0.029	0.775	0.019
1.250	0.802	0.016	0.862	0.029	0.775	0.019
1.312	0.802	0.016	0.862	0.029	0.775	0.019
1.375	0.802	0.016	0.862	0.029	0.775	0.019
1.437	0.802	0.016	0.862	0.029	0.775	0.019
1.500	0.802	0.016	0.862	0.029	0.775	0.019
INFINITY	0.802	0.016	0.862	0.029	0.775	0.019

ITERATIONS 50

example, another 50-iteration run of the base case was conducted. However, this version of the base case was run without invoking the "mean time only" option. The resulting AMORE "curve" is presented in Figure 3.2. Comparison of the graphs in Figures 3.1 and 3.2 provides a visual indication regarding the effects of using the "mean time only" option.

In a similar manner, comparisons of graphical representations of the AMORE output is used in subsequent chapters to describe the effects of changes in selected input parameters.

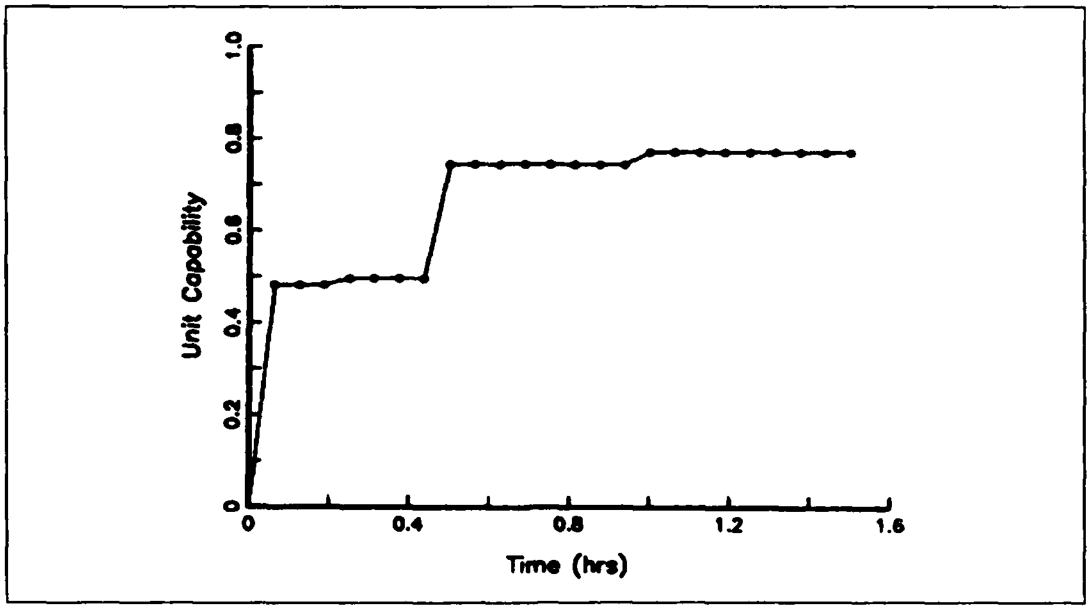

Figure 3.1 Base Case Output (without exponential sampling).

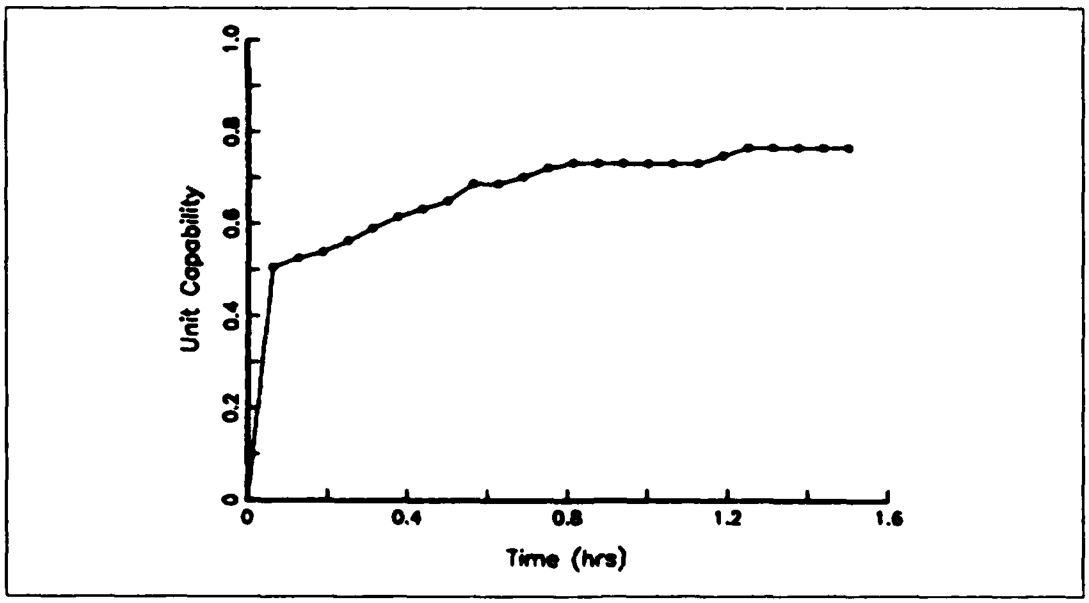

Figure 3.2 Base Case Output (with exponential sampling).

IV. NUMBER OF ITERATIONS

The number of iterations for the AMORE simulation must be specified by the user. An examination of the AMORE model structure, shown in Figure 4.1, reveals that an iteration loop is nested within the simulation loop. Each iteration consists of applying damage to the unit's personnel and equipment, assessing the number of surviving assets, reconstituting mission essential teams, and calculating unit capability at the designated time slices.

Degradation to the unit's personnel and materiel is applied using a Monte Carlo technique based on the input damage probabilities. All calculations are made following each application of the degradation, and the results are then averaged over all the iterations. These results represent the average capability of the unit given many samples of surviving assets as opposed to the capability of the unit given an average set of survivors. Therefore, the number of iterations selected by the user represents the number of stochastic applications of the degradation process, and sufficient iterations are required for the necessary convergence of the results. According to the AMORE User's Handbook [Ref. 4], between twenty-five and fifty iterations have been found to provide generally acceptable convergence.

An examination was conducted in order to demonstrate the effects of the choice of the number of iterations on the AMORE simulation output. A series of AMORE simulations were run using the base case input data and using iteration counts of 5, 20, 50, and 99. This procedure was repeated for three levels of degradation, specified by the three sets of damage probabilities (refered to as PD Sets) listed in Table VIII. For each of the runs, the mean time only option was used.

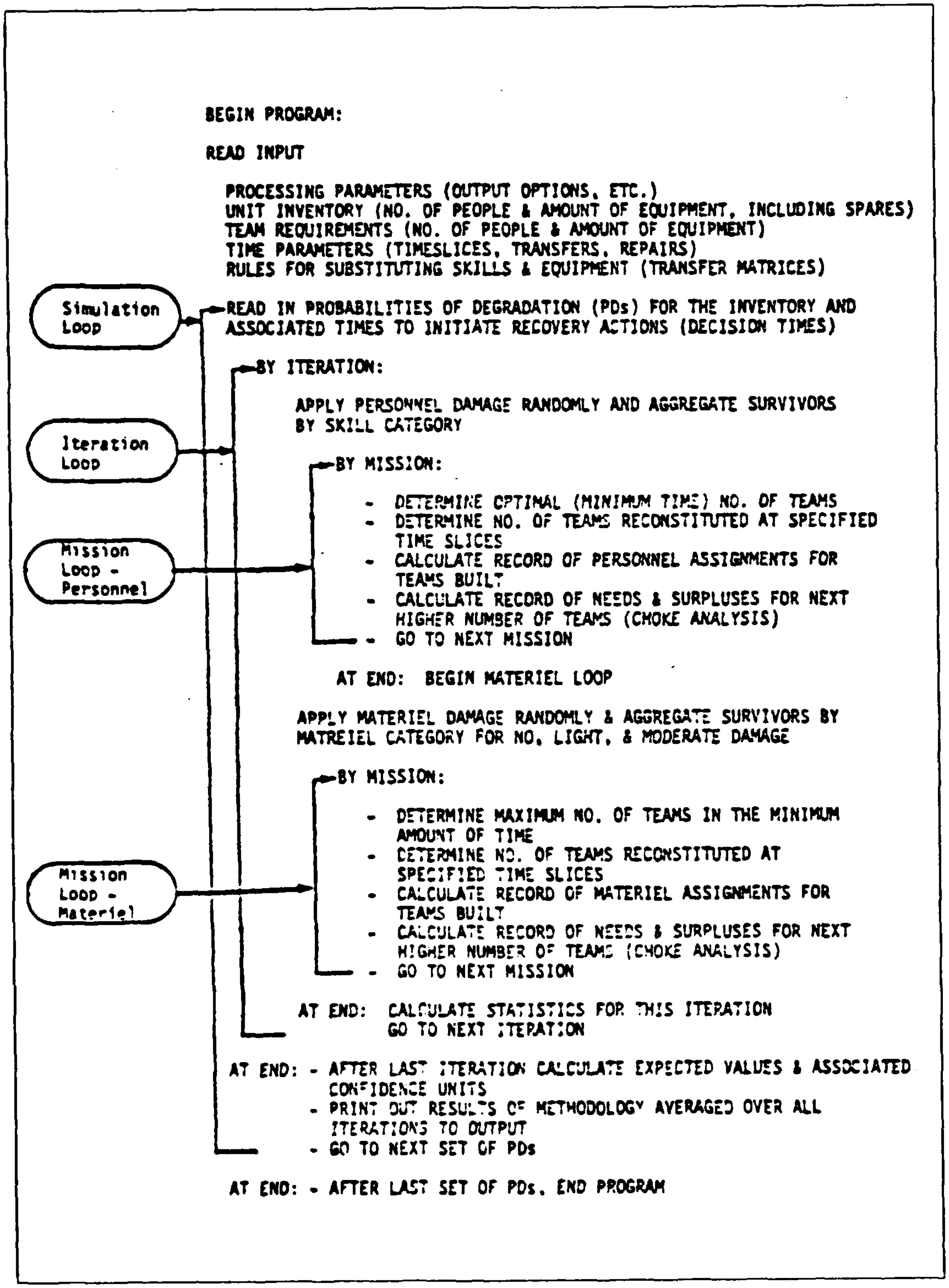

Figure 4.1 AMORE Simulation Structure.

TABLE VIII

Probability of Degradation, (PD sets)

		MATERIEL		
	PERSONNEL	At Least Light Damage	At Least Moderate Damage	At Least Heavy Damage
PD SET 1	10%	13%	8%	5%
PD SET 2	20%	31%	16%	10%
PD SET 3	30%	32%	22%	14%

The output from these simulations is graphically displayed in Figures 4.2, 4.3, and 4.4. Examination of the output displayed in Figure 4.2 reveals an indication of convergence after (to the right of) the 0.4 hour time value. However, in the interval between 0 and 0.4 hours, there appears to be noticeable differences in output capability produced by varying the iteration counts. In this interval, the output values appear to converge to those values produced by the highest iteration count used (ie. 99). Although differences in output values do exist, there is no indication of a lack of convergence. Figure 4.3 reveals consistent results for all four iteration counts used.

These results do support the guidance provided in the AMORE User's Handbook suggesting that 25 or more iterations are necessary to produce acceptable output values. Increasing the number of iterations will permit the AMORE simulation to calculate unit capability based on an increased number of samples of surviving assets. Increasing the sample size should provide a better estimate of the unit capability, while providing a narrower confidence interval for this estimate.

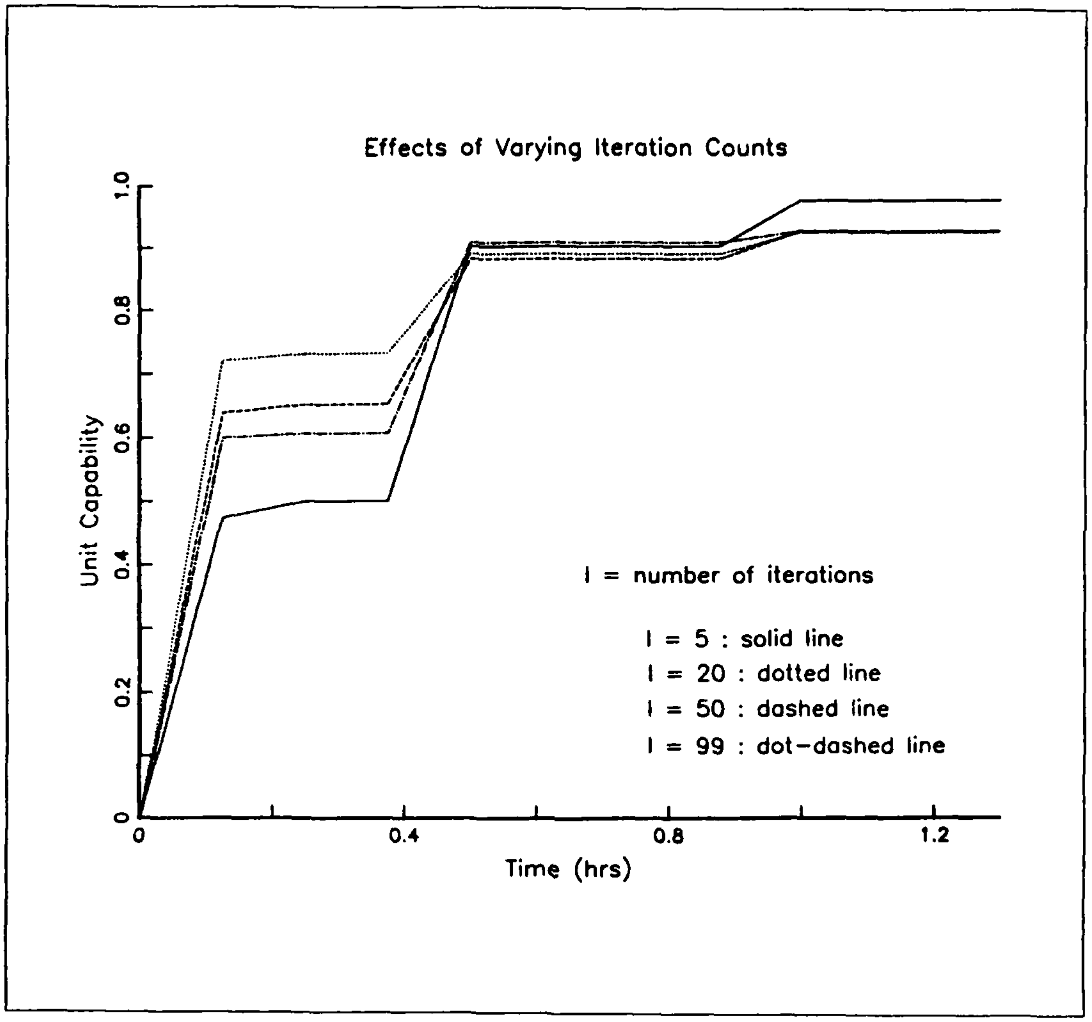

Figure 4.2 Results using PD SET 1.

Users of the AMORE model should select an iteration count sufficiently large enough to ensure statistically acceptable results. This can be done by running the AMORE simulation with the number of iterations set to 25 or more, and then examining the results to insure that the confidence intervals are within the desired limits. Confidence intervals, based on a t-test of significance for a 90% confidence interval, are provided as output by the model. If not

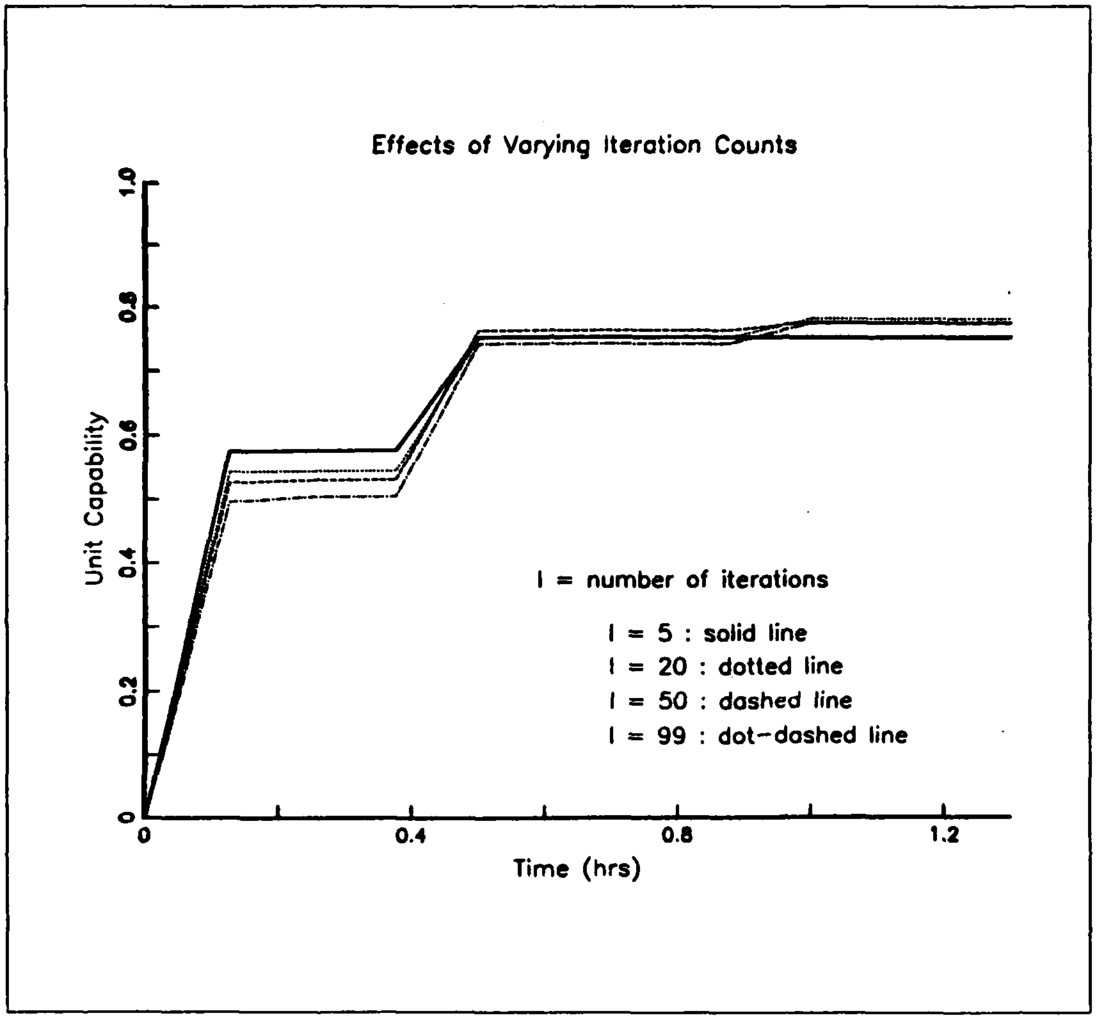

Figure 4.3 Results using PD SET 2.

satisfied, the user may increase the number of iterations, as permitted by local computer resources.

When higher levels of degradation are used, consideration should be given to increasing the number of iterations. Figure 4.4 illustrates the effects of using an insufficient number of iterations while using a higher level of degradation, PD Set 3. Notice that the output capability values produced by using 20 iterations differ from the other output

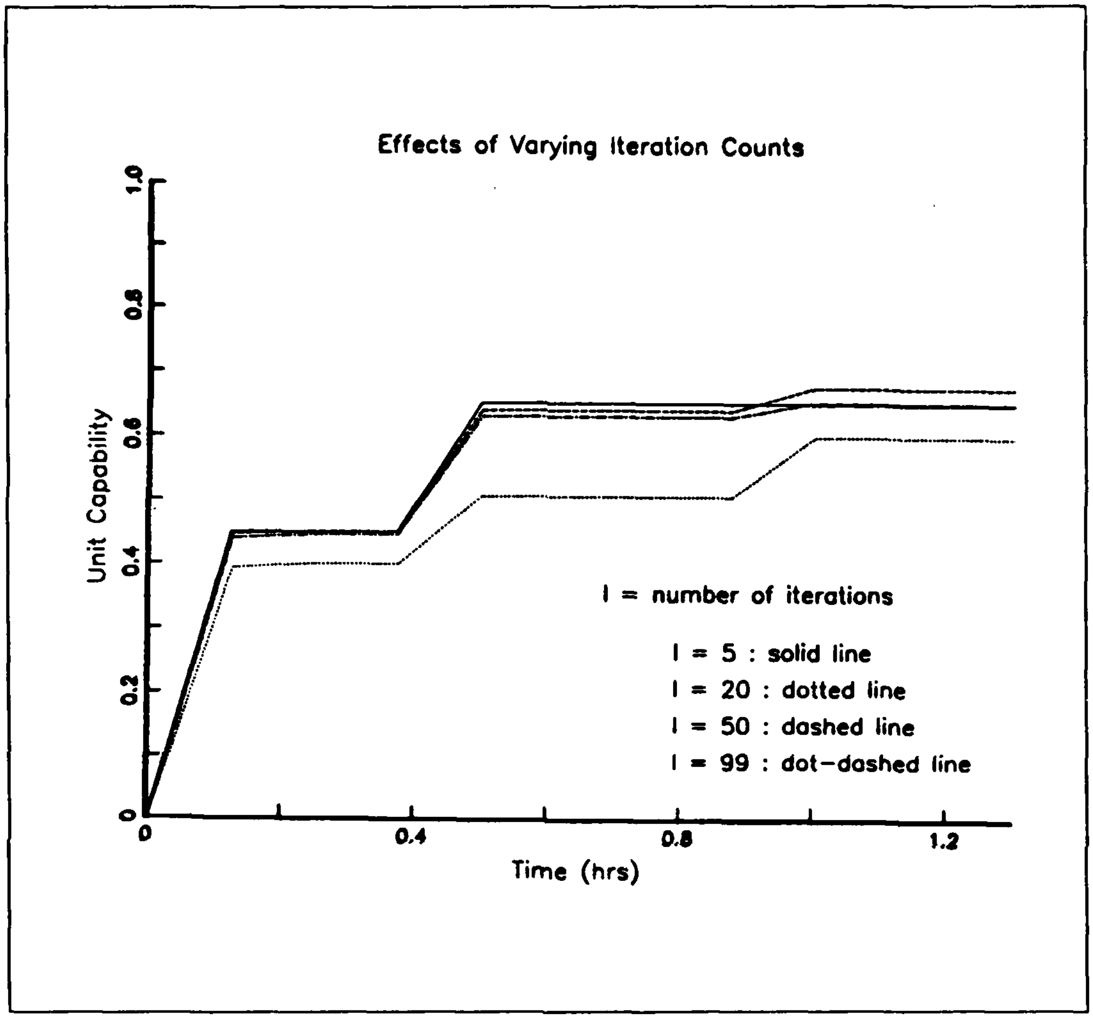

Figure 4.4 Results using PD SET 3.

values generated. These observed differences do not necessarily indicate a lack of convergence. The values produced by using 20 iterations are the result of averaging the capability values obtained from 20 particular samples of surviving assets. It is possible that averaging from a small sample size, such as 20, would yield different results from those obtained from larger samples, particularly when higher levels of degradation are used. Using an increased

number of iterations would increase the number of samples of surviving assets used in determining the average capability values. Therefore, it is recommended that consideration should be given to increasing the number of iterations when higher levels of degradation are used.

V. DEGRADATION LEVELS

The AMORE methodology requires that the user specify as input the probabilities of degradation (PD) for each personnel skill level and for each equipment type. The model simulates personnel degradation by generating for each individual a uniformly distributed random variable which is compared to the input PD for that individual's skill group. If this random variable is less than the specified PD, the individual is declared a casualty and is considered not available for contribution to unit capability.

For the simulation of materiel degradation, the model requires a set of three PDs for each equipment type. These PDs correspond to three levels of damage: light, moderate, and severe. For each item of equipment, a uniform random number is generated and is compared to these PDs in order to determine which category of damage is assessed against each equipment item. Items assessed as lightly or moderately damaged become available after a delay based on time required for repairs. Items assessed as severely damaged are not considered available for contribution to unit capability.

The user's selection of PDs must be based on an analysis of:

1. the scenario(s) to be considered;
2. the unit's mission(s);
3. the unit's configuration and defensive posture;
4. and the source of degradation (ie. the attacking weapon systems).

The User's Handbook [Ref. 4: p.2-76] suggests that this analysis be made with the aid of data provided in the Joint Munitions Effectiveness Manuals (JMEM). Given a specific

scenario, a unit configuration, and an attacking weapon system, JMEM-based analysis can provide source data and probabilities for relative losses of specified items and personnel.

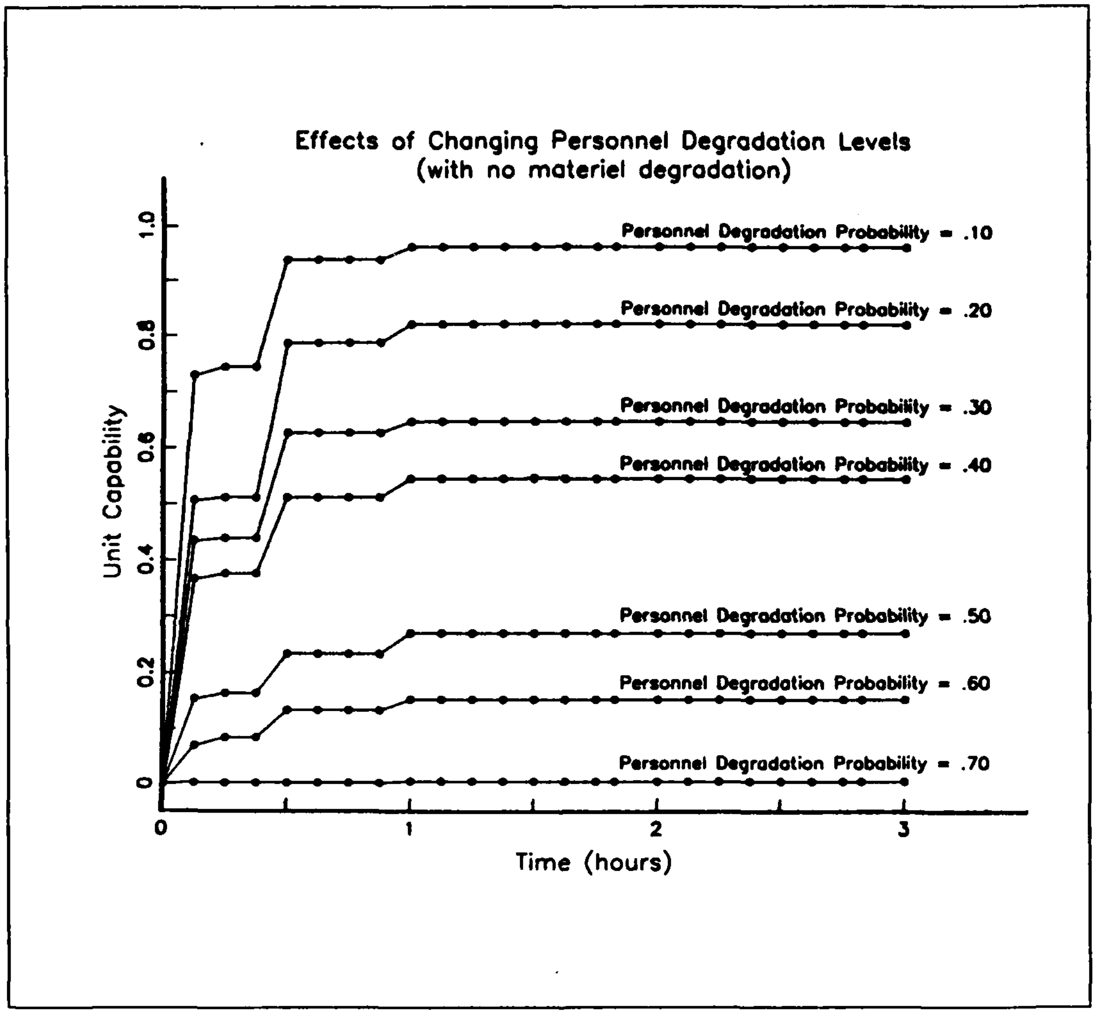

Figure 5.1 Personnel Degradation Levels.

In order to demonstrate the sensitivity of the AMORE simulation to changes in input PDs, the base case was run using various levels of degradation. Degradation

probabilities ranging from 10% to 70% were applied to all personnel skill levels. In order to isolate the effects of personnel degradation on unit capability, equipment probabilities of degradation were set to 0, and the mean time only option used. The results of these runs are displayed in Figure 5.1. As expected, unit capability values progressively decrease as the PD values for personnel are increased.

TABLE IX

Degradation Levels

Probabilities of Degradation:

		MATERIEL		
	PERSONNEL	At Least Light Damage	At Least Moderate Damage	At Least Heavy Damage
Level 1	0%	8%	3%	0%
Level 2	0%	13%	8%	5%
Level 3	0%	18%	13%	10%
Level 4	0%	23%	18%	15%
Level 5	0%	33%	28%	25%
Level 6	0%	38%	33%	30%
Level 7	0%	48%	38%	40%

In order to isolate the effects of materiel degradation on unit capability, this procedure was repeated with personnel PDs set to 0. The materiel degradation levels used are listed in Table IX, and the results of these runs are displayed in Figure 5.2. Again, the unit capability values can be seen to decrease progressively as the PD

values for materiel are increased. The relative flatness of the curves in Figure 5.2 reflects the short (in most cases 0) equipment transfer times and repair times used in the base case. Had values other than 0 been used for materiel transfer times, this flatness would not have been observed. The effects of changes in transfer times on the unit capability curves is discussed in the next chapter.

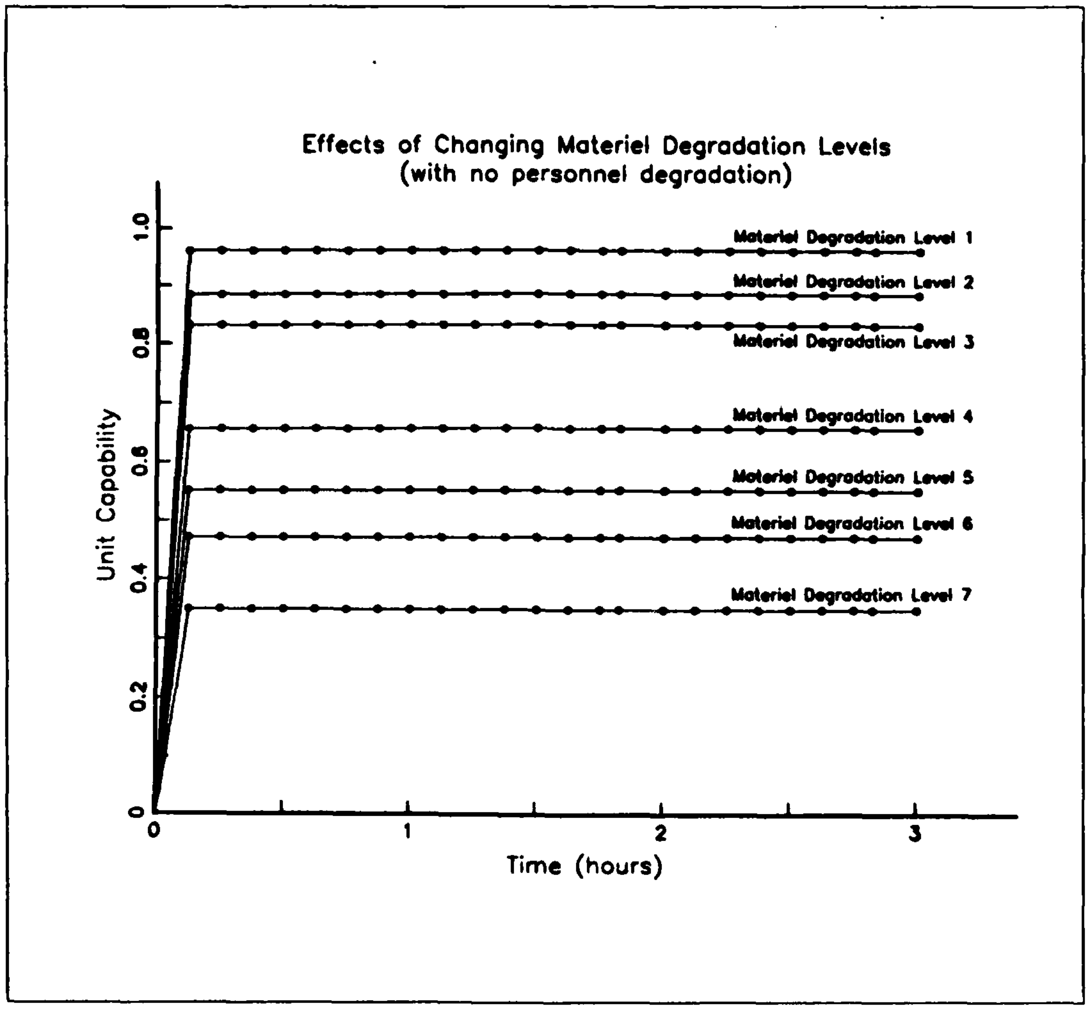

Figure 5,2 Materiel Degradation Levels.

VI. TRANSFER TIME

A. TOTAL TRANSFER TIME

After the onset of some initial degradation, a unit commander must take actions to reconstitute the unit in order to re-establish maximum unit capability. These actions entail the reallocation of available personnel and materiel assets in an attempt to fulfill mission essential requirements. In order to simulate the availability of these resources, the AMORE methodology requires as input an indication of:

1. the time necessary for the substitution of one personnel skill level for another;
2. the time necessary for the substitution of one equipment type for another;
3. the time necessary for the repair of damaged equipment;
4. the time required by the unit commander to assess the situation and make decisions regarding substitutions.

The AMORE methodology defines the total transfer time for a particular personnel skill level to be the sum of the substitution time and the commander's decision time for that particular skill level. Similarly, the total transfer time for a particular equipment type is defined to be the sum of the substitution time, the commander's decision time, and the repair time for that particular equipment type. This total transfer time determines when an individual person or piece of equipment becomes available for substitution or transfer to a position which is a mission essential requirement.

The AMORE methodology requires that the user specify the components of total transfer time for each personnel skill level and for each equipment type. Because this large amount of input information is dependent upon the subjective evaluation of the user, an analysis was conducted to examine the effects of changes in each of the following components of total transfer time: personnel substitution times; equipment substitution times; equipment repair times; and commander's decision times. The results of this analysis are presented in the following sections.

B. PERSONNEL SUBSTITUTION TIMES

The time required for the substitution of one personnel skill level for another is input in the form of a substitution matrix called the personnel transfer matrix. Matrix entries represent the time (in minutes) necessary for the substitution to be operational with an acceptable degree of performance. These times are an indication of how long it would take for an individual in one skill category to become oriented in the mission essential tasks required by another skill category [Ref. 4: p.2-12].

In order to demonstrate the sensitivity of the AMORE simulation to changes in the personnel transfer matrix, three variations of the base case were run. For each of the three variations, all the entries in the base case personnel transfer matrix were multiplied by a constant factor. The factors used were 0.5, 2.0, and 3.0. These trials were run without invoking the mean time only option, and the results of these trials were compared to the results of the base case. These results, displayed in Figure 6.1, illustrate the effects of changing all the entries in the personnel transfer matrix while holding all other inputs constant.

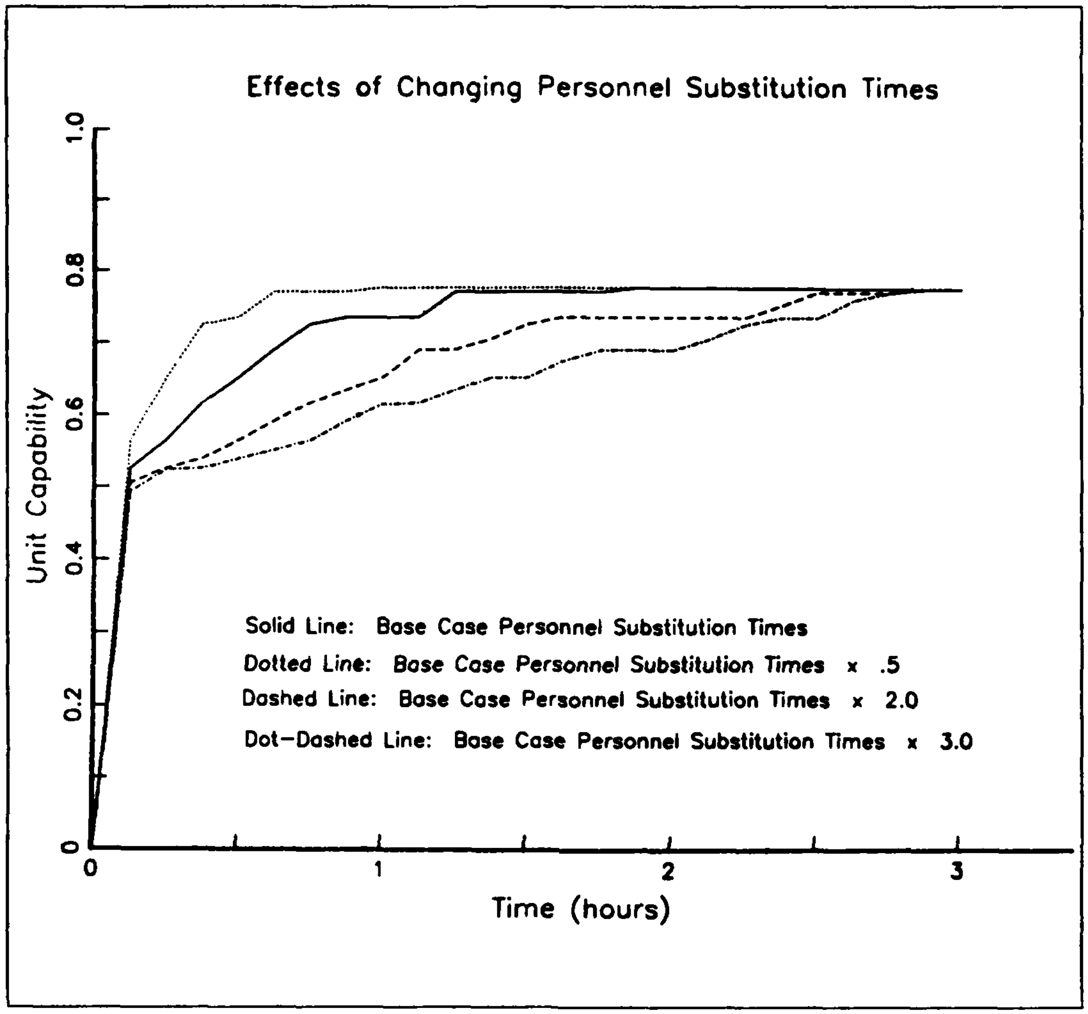

Figure 6.1 Changing Personnel Substitution Times.

Changing the times in the personnel transfer matrix should change the rate of recovery. These changes should not alter the total capability recovered. Examination of the AMORE curves in Figure 6.1 reveals no indication of unexpected results. Decreases in recovery rates are evident, and the maximum capability reached by each of the runs remained unchanged.

C. EQUIPMENT SUBSTITUTION TIMES

The time required for the substitution of one equipment type for another is input in the form of an equipment transfer matrix. The equipment transfer matrix is developed in a manner similar to the personnel transfer matrix. The entries in the equipment transfer matrix represent the time (in minutes) needed to reposition the equipment item to be substituted and to perform any modifications or adaptations to the item.

In order to demonstrate the sensitivity of the AMORE methodology to changes in the equipment transfer matrix, three variations of the base case were run. For each of these three variations, the entries in the base case equipment transfer matrix were modified by adding a constant factor to each base case entry. The results, displayed in Figure 6.2, illustrate the effects of changing all the entries in the equipment transfer matrix while holding all other input constant.

An increase in the equipment substitution times should result in a decreased rate of recovery, while the total capability recovered should remain the same. These expected outcomes are evident in the curves shown in Figure 6.2, and there appears to be no indication of a misrepresentation of expected results.

D. EQUIPMENT REPAIR TIMES

After the application of the degradation process, each item of equipment is categorized as undamaged, lightly damaged, moderately damaged or severely damaged. Undamaged items are available for immediate contribution to unit capability, while severely damaged items are considered not available for any contribution to cabability. Equipment items assessed as lightly or moderately damaged become

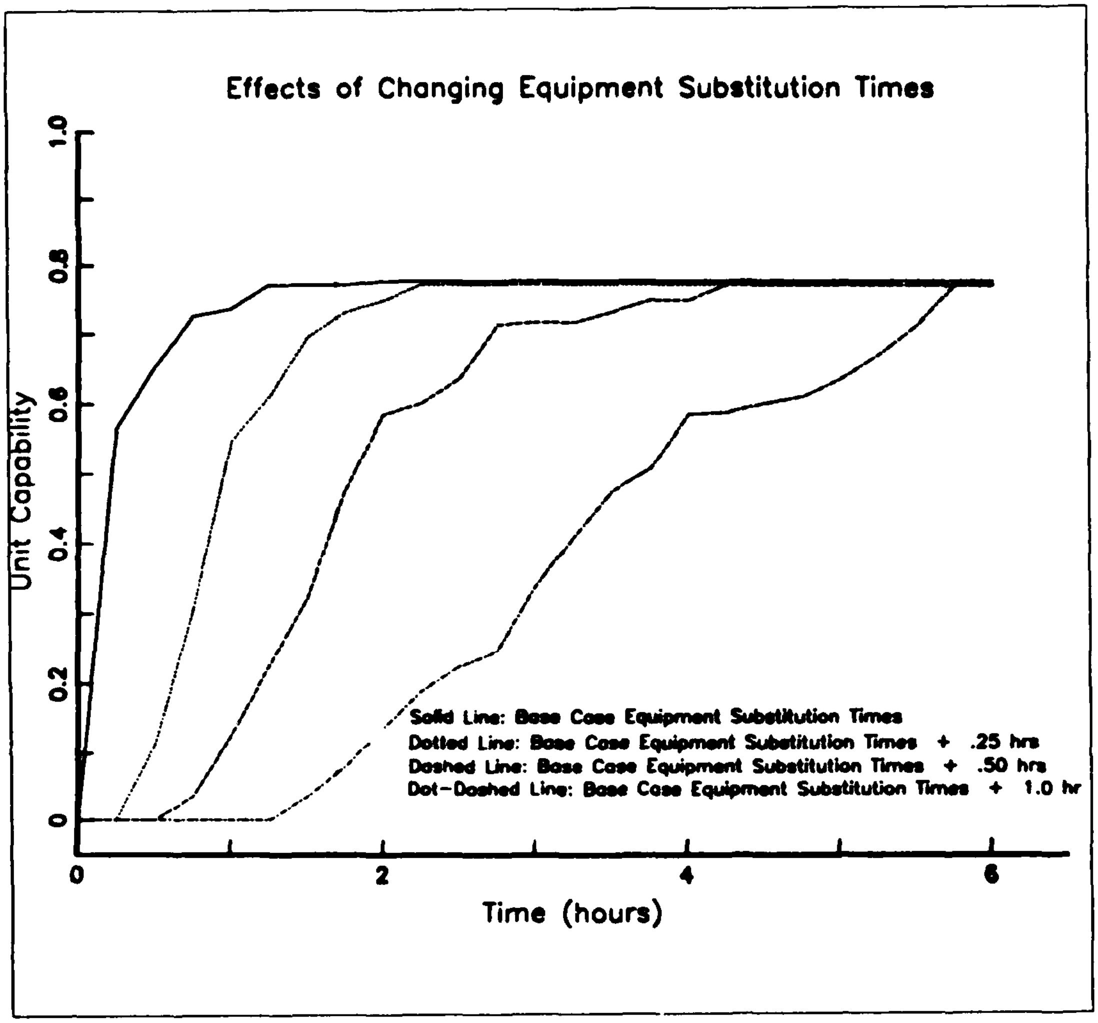

Figure 6.2 Changing Equipment Substitution Times.

available after a delay based on the time required for repairs. The AMORE methodology requires as input an indication of the times required for the repair of lightly and moderately damaged equipment.

In order to demonstrate the sensitivity of the AMORE methodology to changes in the input repair times, the base case was run using various sets of repair time inputs. The effects of increasing equipment repair times are displayed

E. COMMANDER'S DECISION TIME

In order to simulate the need for the unit commander to assess the condition of the unit and to decide how to reorganize, the AMORE methodology requires that an indication of the commander's decision time be provided by the user. The user has the ability to specify a particular decision time for each personnel skill level and for each equipment type.

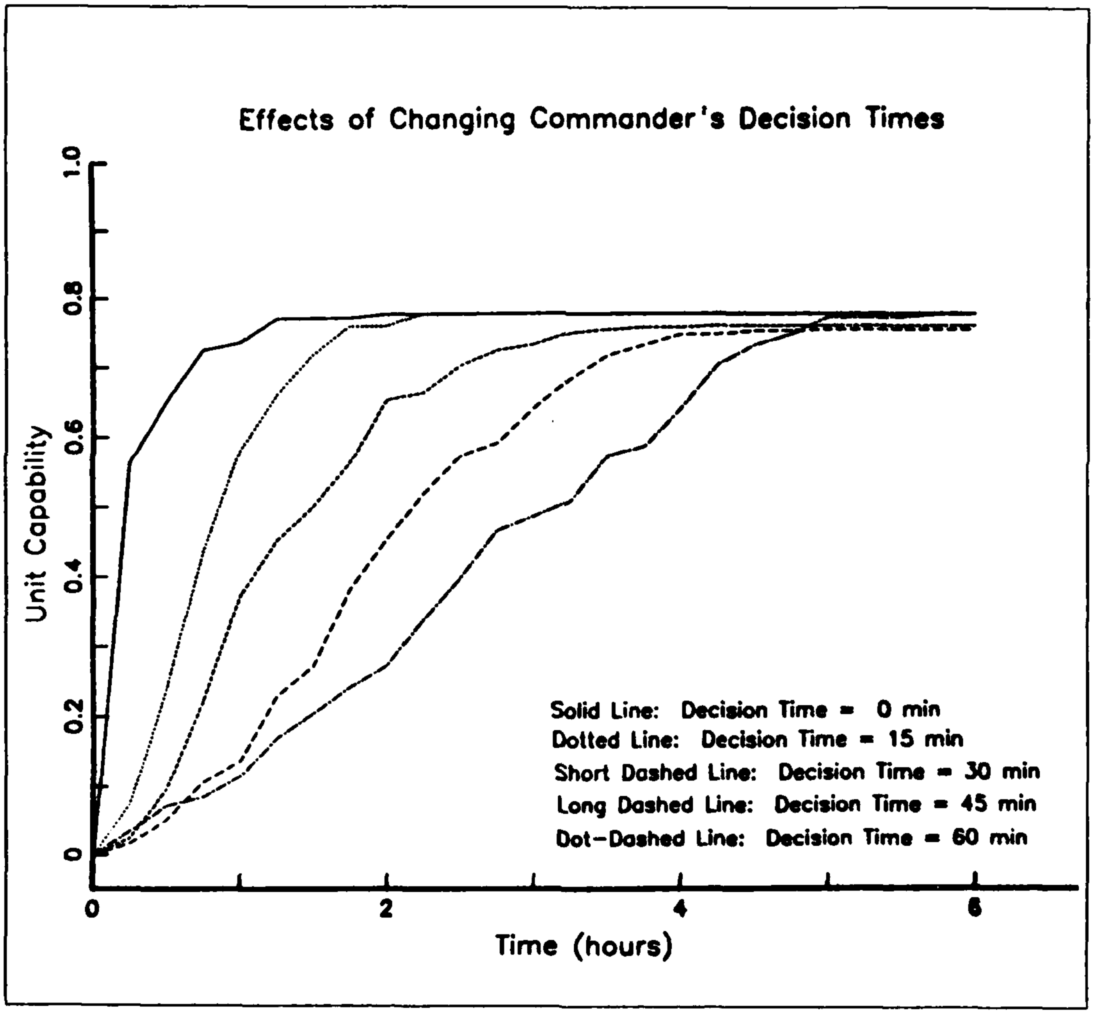

Figure 6.4 Changing Commander's Decision Times.

In order to examine the effects of changes in commander's decision time, four trials were conducted using decision times of 15, 30, 45, and 60 minutes. For each of these trials, the specified decision times were applied to all personnel skill levels and equipment types. The outcome of these trials were compared to the outcome of the base case (decision times = 0), and the results are displayed in Figure 6.4.

The results in Figure 6.4 indicate that, by progressively increasing the commander's decision times, the rate of unit recovery progressively decreases. However, closer examination reveals that the maximum capability achieved in each of the runs were not the same. It was suspected that this anomaly may have been caused as the result of not invoking the "mean time only" option. When this option is not invoked, the total transfer times required for personnel and equipment are sampled from exponential distributions with means determined by the input data. Invoking the "mean time only" option can be used to eliminate the exponential random sampling of total transfer times in the AMORE simulation.

In order to re-examine the irregularities observed in Figure 6.4, another trial was run setting commander's decision time to 60 minutes for all personnel and equipment, and using the "mean time only" option. The results of this trial were compared to the results of the base case run (decision times = 0). A comparison of the results is presented in Figure 6.5.

Examination of Figure 6.5 reveals that increasing the decision times decreases the rate of recovery as expected. However, the maximum capability achieved by this trial (decision times = 60 minutes) exceeds the maximum capability achieved by the base case (decision times =0). These observations indicate that there exists a possibility for the

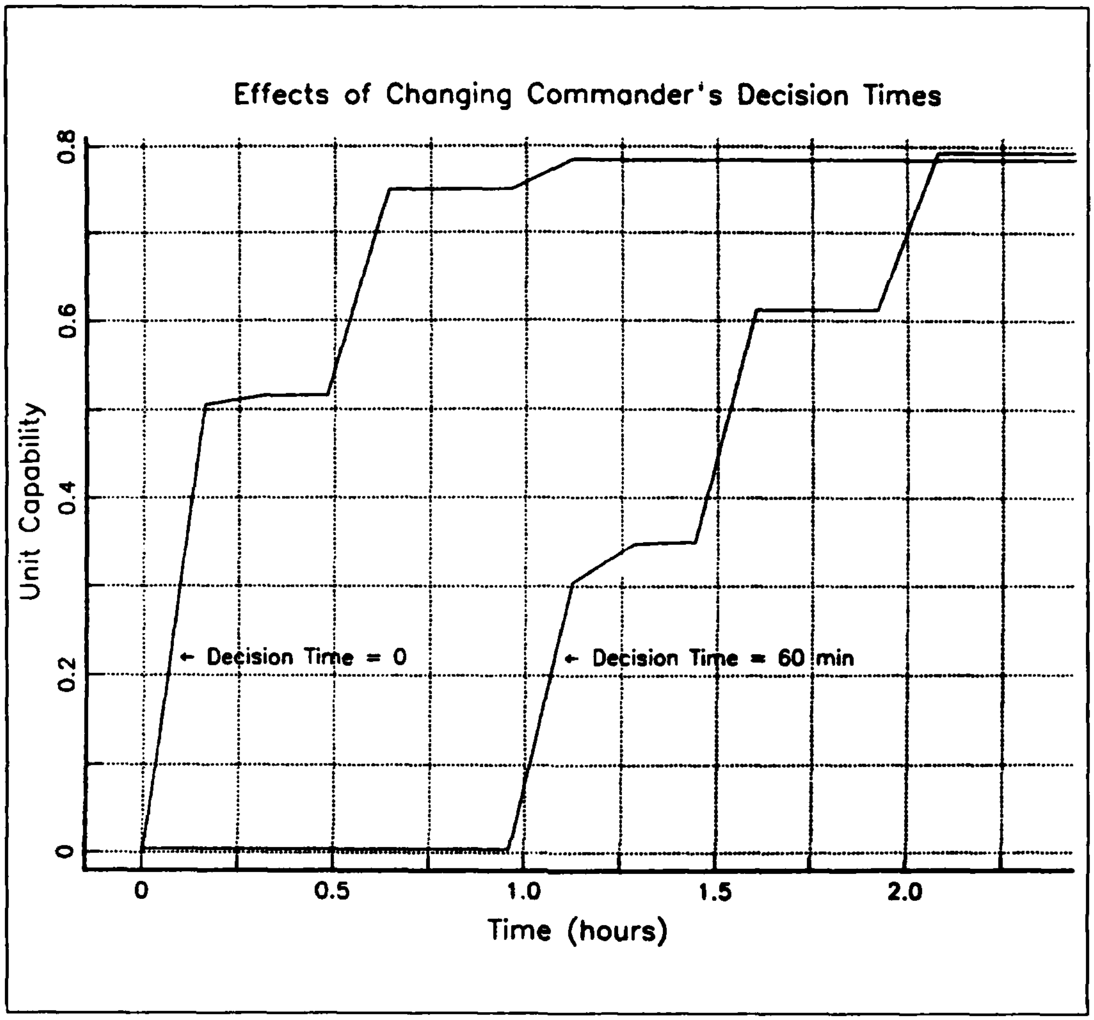

Figure 6.5 Changing Commander's Decision Times.

AMORE simulation to suggest that increases in delay times may increase unit capability.

Examination of the AMORE algorithms reveals that the input commander's decision times are simply added to the input substitution times for the designated personnel and equipment [Ref. 5]. Based on this fact, it should be possible to observe the same results seen in Figure 6.5 by an appropriate selection of input personnel and equipment

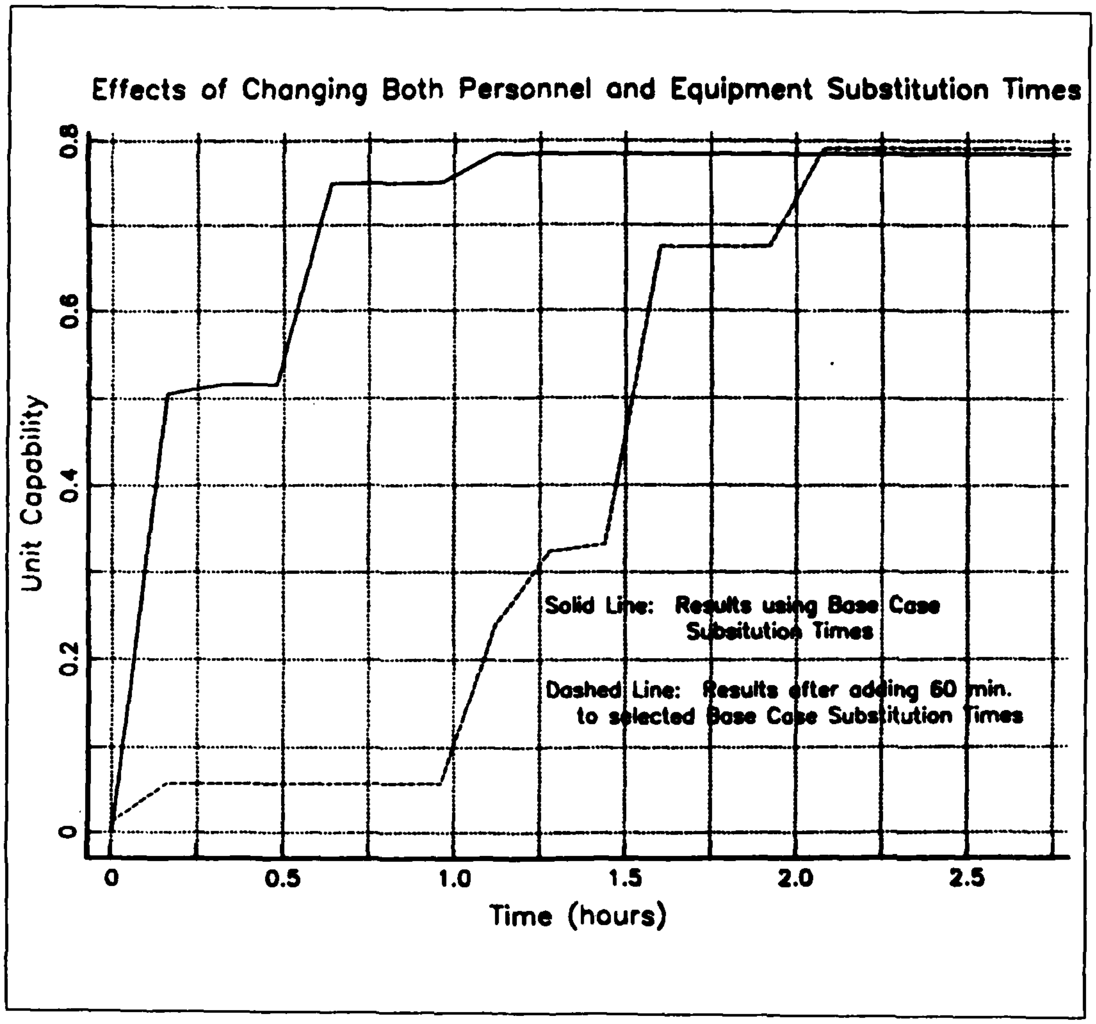

Figure 6.6 Changes to Selected Substitution Times.

substitution times. In order to demonstrate this, another trial was conducted. For this trial, the commander's decision times were set to 0, and increased transfer times were applied to selected entries in the base case personnel and equipment substitution matrices. The results of this trial are displayed in Figure 6.6. Again, the results of the AMORE simulation indicate that a higher level of unit capability can be attained by introducing delays (increasing

input substitution times). These AMORE derived results can be interpreted to suggest that reducing the rate of substitutability between personnel skill types or between equipment types enhances the maximum capability of the unit. This interpretation appears to give a misleading or an inaccurate representation of unit capability, and also raises questions concerning the possible benefits received from the cross-training of personnel. Confidence intervals for the capability values are provided by the AMORE output. It is recommended that, when comparing the results of two or more AMORE runs, an examination of these confidence intervals be conducted in order to determine whether or not a significant difference exists between the maximum capabilities reported. For the example described above, the maximum capability values resulting from these two AMORE runs were found to be not significantly different.

According to the AMORE User's Handbook, changes in the transfer times will change the rate of recovery but will not change the total capability recovered [Ref. 4: p.2-102]. It has been demonstrated that this is not always the case. Reasons for the possible causes of this misrepresentation require a detailed discussion of the underlying algorithms and subroutine structure of the AMORE simulation computer code. A discussion of these structures is presented in Chapter II.

VII. MISSION ESSENTIAL TEAMS

A. DEVELOPING MISSION ESSENTIAL TEAMS

The quantification of the combat capability of a military organization is subject to a wide range of conceptualization and interpretation. The AMORE approach provides a unique method of defining and quantifying the capability of a military unit. This method is based on a preliminary analysis of a specific unit mission, followed by a detailed examination of the unit's assets which are required for contribution to the successful accomplishment of that mission.

The AMORE methodology requires that the user define capability in terms of mission essential teams. Each mission essential team, or MET, represents an increment of capability which contributes to mission accomplishment. In order to assist the user in developing a MET structure for the unit under investigation, the AMORE User's Handbook [Ref. 4: p.2-19] provides the following guidelines:

1. The user should answer the question: if only one increment of capability could be built, what should it contain?
2. Next: if only two increments of capability could be built, what should they contain?
3. The 2nd increment of capability will be the difference between the answers to the above two questions.
4. This process is continued until all functions necessary for mission accomplishment are accounter for.

The AMORE method requires that a separate MET structure be developed for personnel assets and equipment assets.

TABLE X

Base Case Personnel METs

	MET 1	MET 2	MET 3	MET 4	MET 5	MET 6	MET 7	MET 8
Btry Cdr	0	0	0	0	1	0	0	0
First Sgt	0	0	0	0	1	0	0	0
Food Svc Sgt	0	0	0	0	0	0	0	0
Supply Sgt	0	0	0	0	0	0	0	0
NBC NCO	0	0	0	0	0	0	0	0
First Cook	0	0	0	0	0	0	0	0
Armorer	0	0	0	0	0	0	0	0
Cook	0	0	0	0	0	0	0	0
Cook	0	0	0	0	0	0	0	0
Veh Dvr	0	0	0	0	1	0	0	0
Tac Comm Ch	1	0	0	0	0	0	0	0
Tac Wire Ch	0	0	0	0	0	1	0	0
Tac Wire Sp	1	0	0	0	0	0	0	0
Tac Wire Sp	1	0	0	0	0	0	0	0
Plt Ldr	0	1	0	0	0	1	0	0
Plt Sgt	0	1	0	0	0	1	0	0
Veh Dvr	2	1	0	0	0	1	0	0
Fire Dir Off	1	0	0	0	0	0	0	0
Ch FD Cmptr	1	0	0	0	0	0	0	0
Sr FD Spec	1	0	0	0	0	0	0	0
FD Spec	1	0	0	0	0	0	0	0
CP Dvr	1	0	0	0	0	0	0	0
FD Spec	2	0	0	0	0	0	0	0
Ch Sect	1	1	1	1	1	1	1	1
Gunner	1	1	1	1	1	1	1	1
Ammo Tm Ch	1	1	1	1	1	1	1	1
Cannoneer	1	1	1	1	1	1	1	1
Ammo Veh Dvr	1	1	1	1	1	1	1	1
SP How Dvr	1	1	1	1	1	1	1	1
Cannoneer	4	4	4	4	4	4	4	4
Ammo Sect Ch	1	0	0	0	1	0	0	0
Ammo Spec	0	0	1	0	0	0	1	0
Ammo Hdlr	0	1	0	0	0	1	0	0
Sr Ammo Dvr	0	1	0	0	0	1	0	0
Ammo Dvr	1	0	1	0	1	0	1	0

An example of this process is illustrated by examining the personnel MET structure used for the base case, Table X. If only one increment of capability could be built for this howitzer battery, it should contain, as a minimum, the personnel assets required for delivering artillery indirect

fire. In this case, these assets include the personnel needed to operate one howitzer, the personnel needed to accomplish fire direction tasks, and the personnel needed to establish communication between howitzer personnel and fire direction personnel. When the user defines the 1st MET in this way, he is declaring that the mission of providing sustained artillery indirect fire cannot be accomplished with fewer personnel assets than those specified. Examination of the 2nd MET reveals that this next increment calls for additional personnel to man a 2nd howitzer, and personnel needed to supervise two howitzer sections. This procedure was continued in the development of the remaining six mission essential teams.

It is important to note that the AMORE simulation treats the building of capability in a cumulative manner. It accomplishes this by aggregating the assets in the specified sequence of mission essential teams developed by the user. For example, the AMORE simulation would insure that the requirements of the first four METs are satisfied before allowing the 5th MET to be built. Thus, the requirements of the 5th MET (the 5th level of capability) consists of all the assets in METs 1 through 5 in Table X.

B. CHANGING MISSION ESSENTIAL TEAM REQUIREMENTS

It is apparent that the levels of capability reported as output from the AMORE model are strongly influenced by the manner in which the user defines the mission essential teams. In order to demonstrate the sensitivity of the AMORE simulation to changes in user defined MET requirements, the following demonstration was conducted.

The AMORE model was run using three different sets of input data. One set consisted of the base case input data. The 2nd set consisted of the same data with one minor

modification: the number of Cannoneers per team, (5th from the bottom in Table X), was changed from 4 to 3. For the 3rd data set, this number was changed from 4 to 5. For the purpose of this demonstration, this particular skill level (the Cannoneer) was selected as the mission essential team member to be manipulated because this selection provides the most flexibility. There are 4 Cannoneers required for each team, and examination of the personnel transfer matrix, Table III, reveals that there exists numerous other personnel skills which can be substituted into the Cannoneer position. The results of these trials are displayed in Figure 7.1.

Examination of the curves in Figure 7.1 reveals that there exists a noticeable difference in the recovery rates of the three trials. A difference in the maximum capabilities achieved in the three trials is also evident. These results demonstrate that the user's selection of the elements comprising each mission essential team may have a significant impact on the capability levels reported by the model.

C. CHANGING THE NUMBER OF MISSION ESSENTIAL TEAMS

The number of mission essential teams used in defining the capability of a unit is dependent upon the user's analysis of mission requirements and available assets. Two different users may develop two different MET structures for the same organization based on separate, but valid, analyses.. These different analyses of the same organization may be manifested in the form of MET structures which use different numbers of mission essential teams to describe that organization's increments of capability. The number of mission essential teams defined by the user may have a significant effect on the output generated by the AMORE model.

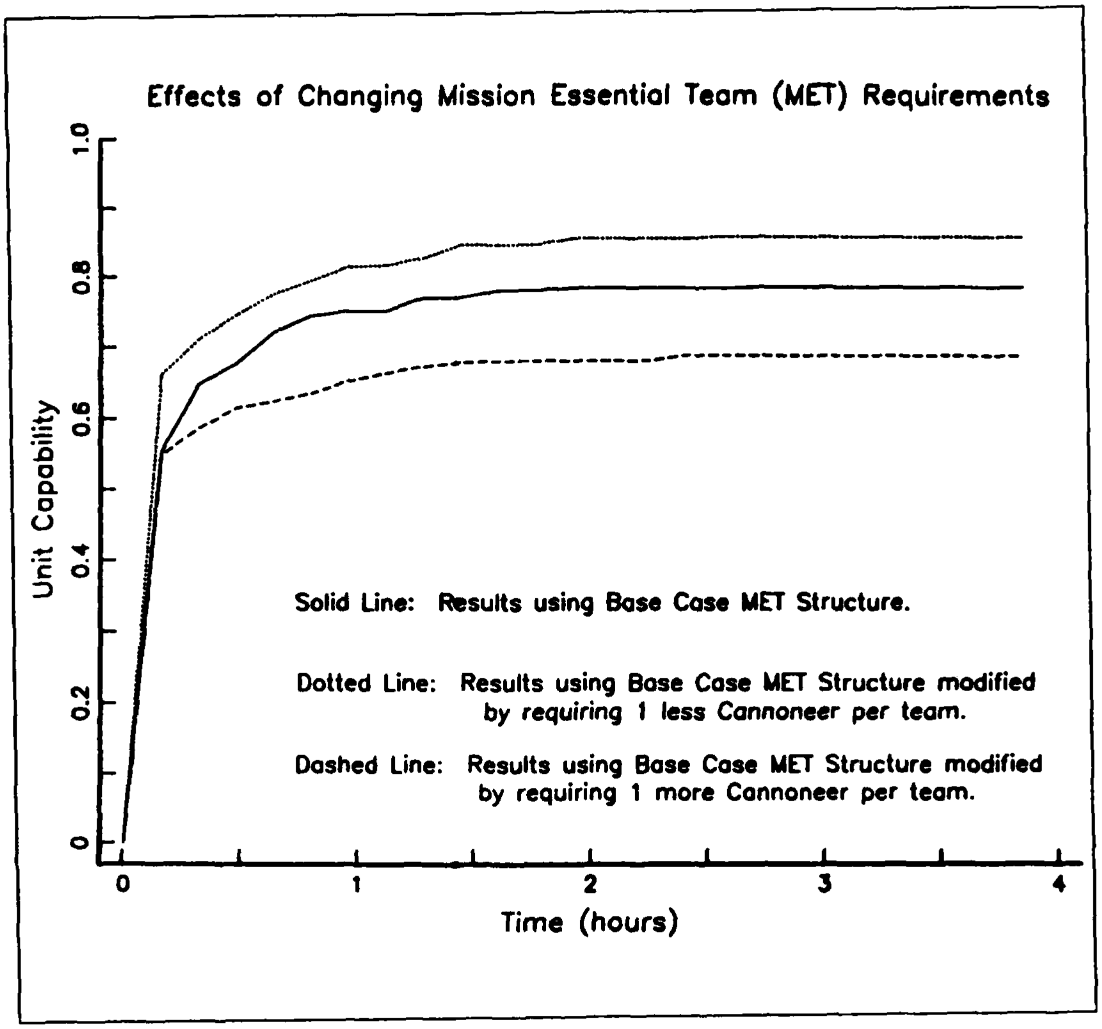

Figure 7.1 Changing MET Requirements.

In order to demonstrate this, two alternate analyses of the howitzer battery mission requirements resulted in the formulation of two additional MET structures (different from the structure defined in the base case). These alternate structures, displayed in Tables XI and XII, both represent valid interpretations of the increments of howitzer battery capability which contribute to mission accomplishment.

TABLE XI

Personnel METS for Alternative A

MET:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Btry Cdr	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
First Sgt	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Fd Svc Sgt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Supply Sgt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NBC NCO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
First Cook	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Armorer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cook	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cook	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Veh Dvr	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Tac Com Ch	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tac WireCh	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Tac WireSp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tac WireSp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plt Ldr	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
Plt Sgt	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
Veh Dvr	2	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
FirDir Off	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ch FD Cmpt	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sr FD Cmpt	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FD Spec	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CP Dvr	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FD Spec	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ch Sect	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
Gunner	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Ammo Tm Ch	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Cannoneer	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
AmmoVehDvr	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
SP How Dvr	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0	1
Cannoneer	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
AmmoSectCh	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Ammo Spec	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0
Ammo Hdlr	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
SrAmmo Dvr	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0
Ammo Dvr	1	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0

TABLE XII

Personnel METs for Alternative B

MET:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Btry Cdr	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
FirstSgt	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
FdSvcSgt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SpplySgt	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
NBC NCO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Armorer	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cook	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cook	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Veh Dvr	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
TacComCh	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TacWirCh	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
TacWirSp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TacWirSp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plt Ldr	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Plt Sgt	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Veh Dvr	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
FirDirOf	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ChFD Cmp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
SrFD Cmp	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FD Spec	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CP Dvr	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
FD Spec	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ch Sect	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0
Gunner	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0
AmmoTmCh	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0
Cannoner	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0
AmmVhDvr	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0
SpHowDvr	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0	0	1	0
Cannoner	1	1	2	1	1	2	1	1	2	1	1	2	1	1	2	1	1	2	1	1	2	1	1	2
AmmSecCh	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
AmmSpec	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
AmmoHnlr	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
SrAmmDvr	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Ammo Dvr	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0

The MET structure displayed in Table XI reveals 16 increments or teams. This structure will be referred to as Alternative A. This structure, which is similar to the one developed for the base case (Table X), is based upon the eight howitzer sections in the battery, with each section consisting of ten men. For the base case, this resulted in 8 mission essential teams. For Alternative A, each ten man section was analyzed to consist of two teams of five men each, resulting in 16 teams. Thus, both the base case structure and the structure for Alternative A represent valid, but different, definitions of increments of howitzer battery capability.

The MET structure displayed in Table XII was developed in a similar manner. This structure will be referred to as Alternative B. Alternative B defines capability with 24 teams, based on another way of organizing the duties within a ten man howitzer section. For Alternative B, each ten man section was analyzed to consist of two teams of four men each, plus a third team consisting of two men dedicated to the performance of support functions within the section. Thus, within each of the eight howitzer sections, there exists three increments of capability, resulting in 24 increments for the entire battery.

In order to demonstrate the sensitivity of the AMORE simulation to changes in the MET structure, the results generated by the input of Alternatives A and B were compared to the results generated by the base case input. A comparison of these outputs is presented in Figure 7.2.

Examination of the curves in Figure 7.2 reveals that different recovery rates were reported for each of the three trials. There is also an indication that the maximum capabilities achieved by each of the trials were not the same.

These results should not be used to determine if one alternative MET structure is more acceptable than another.

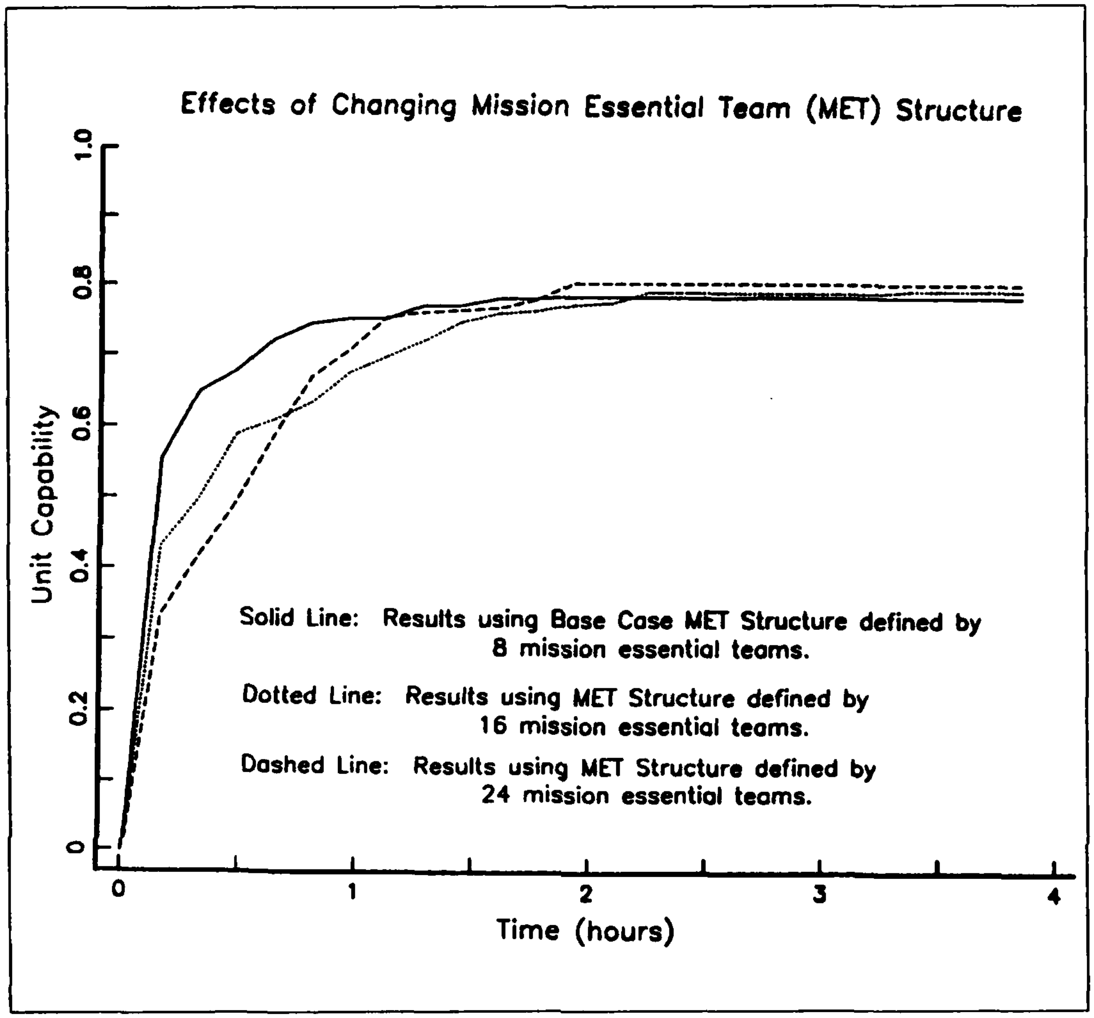

Figure 7.2 Changing MET Structure.

The results of these trials serve to demonstrate that the number of mission essential teams used as input to the AMORE model can result in a noticeable difference in the output generated by the model. For example, the curves displayed in Figure 7.2 show that, at timeslice = 0.5 hours, there appears to be large differences between the reported capabilities of the three MET structures. In order to understand how the number of mission essential teams impacts on

the output of the AMORE model, a detailed discussion of the algorithms and subroutines used in this simulation is required. A detailed explanation of how the input MET information interfaces with these subroutines is presented in Chapter II.

VIII. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

The results presented in Chapters IV through VII provide guidance and recommendations regarding the formulation of the AMORE input information. These chapters also demonstrate how selected changes in the input information can affect the output generated by the model. An explanation of how these changes produced the demonstrated results has been provided through an analysis of the algorithms used in the AMORE model. Conclusions based upon the results of this analysis are summarized below.

1. The AMORE methodology interprets capability strictly as a function of the availability of personnel and materiel assets. Other measures of performance are not considered by this approach.
2. The AMORE approach of transforming availability into capability is based upon a number of simplifying assumptions, which may present limitations on the applications of the model. Some specific limitations are discussed in the Recommendations section below.
3. The results obtained using the particular base case organization chosen for this investigation illustrate that the AMORE model displays sensitivity to changes in each of the input factors examined. For the base case, controlled changes in the input factors produced the expected consequences in all cases except for those cases involving changes to input transfer times. However, the unexpected consequences obtained by increasing selected transfer times can be reduced or eliminated by increasing the number of iterations.

4. The mission essential team input can significantly affect the output capabilities reported by the model. Because the model treats the mission essential teams as the building blocks of capability, alternative MET structures have a more significant impact on resultant capbility analyses than changes in any other input factors.

B. RECOMMENDATIONS TO USERS OF THE MODEL

Based on the results of this investigation, the following recommendations are provided:

1. Users of this model must be cognizant of the AMORE definition of capability. Based on this definition, the user must be satisfied that the desired measure of effectiveness is consistent with the AMORE measure of effectiveness before any application of the methodology is attempted.
2. Users of this model should have a thorough understanding of the assumptions inherent in the use of the AMORE algorithm in order to conduct a valid interpretation of the AMORE results. These assumptions are listed in Chapter II.
3. The results of an AMORE analysis should be used to provide insight or to identify trends in organizational capability. However, the output from the model should not be used to provide point estimates of capability. For example, the model can be used for purposes of comparison, as an aid to evaluating candidate organizational structures. The model should not be used to predict the effectiveness of a particular organization in a specified scenario, based upon capability levels reported as output from an AMORE simulation.

4. It is recommended that the AMORE output not be used to compare the recovery rates of candidate organizations, unless the maximum capabilities generated by the AMORE runs for the organizations are the same. The user must be aware that the recovery rates reported by the model are based upon a solution to the linear program which maximizes capability, not recoverability. Recovery rates based upon sub-optimal solutions to the assignment problem are not reported by the model.
5. It is recommended that the user examine the confidence intervals which are provided as output for each of the capability values reported. When comparing the results of two or more complete runs, an examination of these confidence intervals will indicate if a significant difference exists between the maximum capabilities reported for each run. The user may increase the number of iterations in order to increase the size of the sample of survivor sets, thus decreasing the confidence intervals until the desired limits are obtained.
6. In the formulation of input information required by the model, the user should give considerable emphasis to the Mission Essential Team input. The correct formulation of this input information is critical to the valid application of the AMORE methodology. The formulation of this input factor requires the user to define explicitly the structure to be used by the model for generating and reporting quantifications of organizational capability. Furthermore, the user is forced to define capability in discrete increments which are treated as equivalent slices of capability by the AMORE model. For many organizational mission requirements, this structuring may not be

appropriate. An in-depth preliminary analysis of the unit's mission must be conducted in order to determine the suitability of the current AMORE requirements for the organization under examination. In conducting this analysis, it is recommended that the user initially not consider the available organizational assets, but consider only the mission requirements of the unit under investigation. Based on an analysis of these requirements, the user should then attempt to identify those organizational assets which can be used to constitute teams which contribute equally to the fulfillment of the mission requirements. For non-homogenous units and for organizations with diversified mission requirements, the user may be restricted to applying the AMORE simulation to those specific mission requirements for which equal increments of capability can be defined.

C. RECOMMENDATIONS FOR MODEL ENHANCEMENT

Based on an examination of the AMORE algorithm and the results of the base case trials, the following recommendations for model enhancement are provided.

1. For those applications in which the user desires to examine the effects of personnel cross-training or equipment inter-operability, the AMORE simulation in its present form may provide misleading results (as demonstrated in Chapter VI). These misrepresentations are the result of the process by which the AMORE simulation is designed to select values from a generated random number stream. Values are selected from different points in the random number stream based upon the transfer times input to the model. These values are then used in a Monte Carlo process

which determines the sets of surviving assets. In some instances in which the user desires to examine the effects of changes in transfer times, it may be desireable to insure that the sample sets of survivors between sequential AMORE runs are consistent. It is recommended that an additional and alternative version of the AMORE simulation, in which random numbers are selected from the same point in the generated stream, be provided for this purpose.

2. The current requirement to define capability in terms of equally weighted increments is not readily suitable to non-homogenous organizations or organizations with diversified mission requirements. As a proposed enhancement to the current method, it is recommended that the AMORE model be revised to permit the user to specify mission essential teams which will not necessarily be treated as equally weighted increments of capability. This can be accomplished by requiring the user to provide, in addition to the required MET input, a scale of values ranging from 0 to 100%, with one value corresponding to each cumulative MET defined. For example, consider a situation in which the user specifies, as input, 10 mission essential teams. If, during one iteration of the AMORE run, surviving assets were determined to fulfill all the requirements of the first 8 METs, a value of 80% capability would be calculated and recorded by the model, under the current version. Under the proposed revision, the same surviving assets which fulfilled all the requirements of the same 8 METs could correspond to 50%, 91%, or any percentage defined by the user to represent the capability available in the assets of those 8 increments. This recommendation would entail some major modifications to the existing

AMORE computer code, and would involve additional storage of input factors to be used within the iteration loop. However, this enhancement would provide greater flexibility to the user and increased applicability of the model for future use.

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